THE REGULATORY LANDSCAPE OF MERCURY

MANAGEMENT IN THE NORTHEASTERN

UNITED STATES

THESIS

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TABLE OF CONTENTS

Page

LIST OF TABLES

Table **Page**

LIST OF FIGURES

Figure **Page**

ABSTRACT

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This research assesses the regulatory landscape of mercury management in the northeastern United States through the examination of state-level environmental management programs in twenty northeastern states. Previous research regarding mercury in the environment primarily focuses on emission, transport, and deposition of mercury, and human health impacts. This research seeks to fill the gap in mercury research addressing environmental regulations and management strategies. The study of an environmental toxin through the lens of a regulatory landscape offers a geographic understanding of management actions across the region. Distinct geographic patterns of regulation are evident across the region. Within the study area a variety of regulatory landscapes are present. The New England region demonstrates the most comprehensive

regulatory landscapes, the Great Lakes region is inconsistent, and the southern portion of the study area is highly fragmented. These patterns illustrate a wide variance in issue-salience, state-level funding, and management approaches toward mercury in the environment. This variance is the result of differences in state-level environmental management approaches magnified by a lack of federal directives on addressing mercury as an environmental pollutant. Certain states are defining their own regulatory landscape in the absence of federal action by regulating mercury in the waste stream, water discharges, and atmospheric sources of mercury emissions. Other states are more passive, awaiting federal action to adopt an existing regulatory landscape rather than creating their own.

CHAPTER I

INTRODUCTION

Since the promulgation of the Clean Water Act (CWA) in 1972, the water quality of United States surface waters has significantly improved (Knopman and Smith 1993; Keller and Cavallaro 2008). Prior to this landmark legislation, approximately two thirds of surface waters in the United States failed to meet basic water quality standards, and many water bodies were so polluted that swimming, fishing, and recreation were not safe (Grumbles 2008). In the late 1960s, images of the Cuyahoga River on fire, and raw sewage flowing into surface waters fueled growing concerns among the public regarding water quality (Knopman and Smith 1993; Copeland 2002). Social awareness of environmental pollutants grew during this time. Books such as Rachel Carson's 1962 bestseller, *Silent Spring* prompted a broader social movement aimed at protecting the environment. The federal government responded in 1969 by passing the National Environmental Policy Act (NEPA), requiring all federal agencies to perform a preemptory assessment of the impacts of new projects, and setting the stage for enhancements to most federal environmental regulations. Although this new *environmental movement* had many dimensions, at the center was an emerging awareness of declining water quality and a societal understanding of the environmental and health impacts of water pollution (Knopman and Smith 1993).

Despite the fact that the CWA's ambitious goals of remediating all United States surface waters to "fishable and swimmable" quality remain elusive, many areas have improved (Copeland 2002; Grumbles 2008; US EPA 2010b). Improvements in water quality is the direct result of permitting requirements for entities that directly discharge wastes into surface waters, and command and control technologies that remove pollutants from wastewater prior to discharge into water bodies (Grumbles 2008; US EPA 2010b).

The success of the CWA has been achieved by creating a national regulatory framework that establishes and enforces effluent limits for point source dischargers that discharge directly into water bodies (Copeland 2002; Lyon and Stein 2008). Historically, the CWA focused on point source discharges into surface waters and conventional pollutants such as suspended solids and bacteria (Copeland 2002; US EPA 2010b). The United States Environmental Protection Agency (US EPA) has more recently focused regulation upon the control of toxic pollutant discharges, particularly persistent, bioaccumulative, and toxic (PBT) pollutants (Copeland 2002; Bester et al. 2008; US EPA 2010f). PBT pollutants do not break down in the environment, and instead these pollutants persist and increase in concentration as they undergo metabolization and cycle through the trophic system (Morel, Draepiel, and Amyot 1998; Driscoll et al. 2007; Chumchal et al. 2008b; US EPA 2010f). PBT pollutants are of great concern because they transfer easily between air, land, and water, and they span geographic and generational boundaries (US EPA 2010f). Though most PBT pollutants are widespread, mercury is more ubiquitous than most PBT pollutants affecting United States' surface waters (US EPA 2010f).

Mercury is a water pollutant of particular concern because it is a persistent environmental toxin that adversely affects human health and compromises the integrity of aquatic ecosystems (Yokoo et al. 2003; Axelrad et al. 2007; Driscoll et al. 2007). A potent neurotoxin, mercury is particularly harmful to the neurological development of the fetus, infant, and young child, and has the potential to cause adverse health effects among adults (Amin-Zaki et al. 1974; US EPA 2006a; Virtanen et al. 2007; Oken and Bellinger 2008).

Many natural and anthropogenic sources emit mercury (Fitzgerald et al. 1998; Pacyna et al. 2006; Driscoll et al. 2007; Lindberg et al. 2007). This research focuses on the anthropogenic sources of mercury such as publicly owned treatment works (POTWs), coal-fired power plants, and mercury in the waste stream. Coal-fired power plants are the largest anthropogenic source of mercury emissions in the United States (US EPA 1997; Pacyna et al. 2006). Airborne mercury emissions are deposited everywhere, including onto the surfaces of water bodies, ultimately contaminating wildlife and humans (Fitzgerald et al. 1998; Morel, Kraepiel, and Amyot 1998; Driscoll et al. 2007). Human exposure to mercury occurs primarily through the consumption of contaminated fish (Davidson et al. 1998; Moya 2004; US EPA 2006a).

Mercury contamination of aquatic organisms, particularly fish, is an emerging water quality concern because it represents a risk to human health and is indicative of impaired ecosystems. Aquatic ecosystems are an important source of food, water, and recreation; society relies on clean water resources for most daily activities. Degradation of water quality affects the availability of water resources for a variety of uses (recreation, wildlife, and drinking water). Exposure to mercury is harmful to wildlife and humans, compromising biologic and reproductive processes. The impacts on human health include learning disabilities, compromised motor function, and vision impairments (Amin-Zaki et al. 1974; Bjornberg et al. 2003; King et al. 2003; Axelrad et al. 2007). Estimates indicate health effects resulting from mercury exposure threaten the health of approximately 630,000 infants each year in the United States (US EPA 2006a).

Mercury in the environment is an emerging concern among environmental managers, electricity providers, and human health advocates (US EPA 2006a; Burger and Gochfeld 2008). Environmental managers must contend with contaminated fish populations and the resulting human health effects, as well as reduced viability of aquatic ecosystems (Maddock 2004). Energy producers will eventually be responsible for reducing mercury emissions in order to protect human and environmental health (Smith and Trip 2005; McCarthy 2007; Sullivan et al. 2008). The ability to protect human health from deleterious effects of mercury contamination is dependent upon the ability of government regulation to effectively reduce mercury in the environment.

Despite decades of research on mercury in the environment, much uncertainty remains regarding risks of exposure, the transport, and deposition of mercury emissions, and biogeochemical cycling of mercury in aquatic and terrestrial ecosystems (Amin-Zaki 1974; Harada 1995; Pacyna and Pacyna 2002; Rice, Schoney, and Mahaffey 2003; Pacyna et al. 2006; US EPA 2006a). An incomplete understanding of mercury in the environment impedes the development of adequate policies and regulation (Pacyna et al. 2006; Lindberg et al. 2007). Debate persists among stakeholders regarding what is sound science, and how to use science to develop management strategies (Maddock 2004). This climate of uncertainty, coupled with a lack of comprehensive federal regulations regarding mercury, has created a fragmented regulatory landscape of mercury management.

The regulatory process of lead offers some insight into how scientific knowledge about a heavy metal translates into public health policy. The political struggle to remove lead additives from gasoline lasted three decades. This public-policy process led to changes in both scientific and public perceptions regarding lead toxicity, and realizations that developing brains are the most prone to adverse health effects from lead exposure (Kraft and Scheberle 1995; Needleman 2000; Bellinger and Bellinger 2006). As the scientific community came to understand that even low amounts of lead exposure resulted in significant health impacts, the regulatory framework evolved to lower acceptable environmental thresholds (Fulton et al. 1987). Ultimately, the goal of lead-hazard management evolved to strive for complete removal of lead from as many processes and products as possible in order to protect children's health (US DHHS 1991; Kraft and Scheberle 1995). Despite regulating lead out of gasoline and paint, child exposure to lead paint in old homes and toys from overseas persists; however, a combination of federal regulation and industry incentives reduced the overall exposure within the U.S.

The lead experience illustrates the importance of responding quickly and appropriately to human health risks. The process of lead regulation also demonstrates the extent to which solving environmental problems related to industrial pollution often requires the cooperation of science, government, and industry. These observations are particularly true of mercury management given the ubiquity of mercury emissions associated with energy production and industrial processes (Bellinger and Bellinger 2006). If history is any indicator, government regulation must prompt and sustain this tenuous collaboration.

Existing state-level management approaches will likely provide the architecture for future federal regulations. A clear articulation of, and comparison between, state-level approaches to mercury management is lacking in the current scientific literature. Therefore, the purpose of this research is to examine the regulatory landscape of mercury management in the northeastern United States. This research characterizes the regulatory landscape that has evolved across twenty northeastern states by examining state-level actions to address mercury in the environment.

CHAPTER II

MERCURY IN THE ENVIRONMENT

Mercury is a naturally occurring element and a pervasive environmental toxin, stored in rocks, sediments, and soils (Morel, Kraepiel, and Amyot 1998; US EPA 2006a). Industrial processes release otherwise sequestered mercury into the environment. Mercury is a pollutant that persists in the environment, is highly toxic to humans, and increases in concentration as it cycles through ecosystems. The behavior of mercury in the environment has led the US EPA to list mercury as a priority pollutant and a PBT pollutant. PBT pollutants are an emerging concern in water management because these toxics span geographic and generational boundaries, transferring easily between land, air, water, and fish. Mercury is the most widespread PBT pollutant in the United States (US EPA 2008).

Mercury occurs in three forms in the environment: elemental mercury, organic mercury compounds, and inorganic compounds. Each form of mercury has unique physical and chemical properties and is associated with certain fuels and combustion processes. Once a source emits mercury, deposition may occur directly into water bodies or onto the land and plant surfaces within a watershed. Following deposition, mercury is converted into methyl mercury, a highly toxic form of mercury, through a process called methylation in which the metabolic activities of bacteria convert inorganic mercury compounds into methyl mercury (Jackson 1997; Chumchal et al. 2008a).

The elusive nature of mercury pollution is a highly contentious issue characterized by extensive debate. Uncertainty surrounding the biogeochemical behavior of mercury in the environment creates controversy in the management and regulatory process. The dominant themes nested within the debate over management and regulation of environmental mercury includes source attribution, global transportation, deposition patterns and local hot spots, and human health effects. The lack of consensus on these key issues complicates the management process and, coupled with state-level enforcement of federal environmental laws, serves to create a diverse regulatory landscape across the United States.

Mercury Emissions

The majority of mercury emissions in the United States originate from large-scale industrial processes, including: coal combustion, waste incineration (including medical, municipal, and hazardous waste), and cement production, among other sources (Lindqvist et al. 1991; Rasmussen 1994; Pacyna and Pacyna 2002; US EPA 2006a; Demirak 2007; US EPA 2009a;). Federal regulations mandating large reductions in mercury emissions from municipal and hospital/medical/infectious waste (HMIW) incinerators have led to significant declines in domestic mercury emissions over the past decade. Coal-fired power plants are responsible for the majority of industrial mercury emissions, emitting over 40 percent of total anthropogenic emissions in the United States (US EPA 2006a; Driscoll et al. 2007). In May 2009, the US EPA proposed rules to control emissions from cement-production facilities with the goal to reduce annual emissions by approximately 81 percent (11,600 lbs.) by 2013 (EPA 2009a). While these regulations represent a significant reduction in domestic mercury pollution, emissions from coal-fired power plants remain unregulated by the federal government.

While many domestic sources of mercury have been identified and quantified, most global sources of mercury have not been identified. The specific environmental pathways from emissions source to deposition and subsequent contamination remains unclear (US EPA 2006a). Uncertainty complicates source attribution, and represents a significant barrier to the successful management of mercury (Pacyna and Pacyna 2002; Lindberg et al. 2007).

Mercury Transport and Deposition

Airborne mercury travels through the atmosphere until deposition, either directly into water bodies or onto land (Mason, Fitzgerald, and Morel 1994). Deposition may occur near the emissions source (i.e. deposited locally or regionally), or mercury may be transported long distances over a period of years before deposition occurs (i.e. transported globally) (Fitzgerald et al. 1998; Morel, Kraepiel, and Amyot 1998; Pacyna and Pacyna 2002; Jiang, Shi, and Feng 2006; Pacyna et al. 2006). The distance mercury emissions travel before deposition depends upon prevailing winds and precipitation patterns. The form of mercury emitted also influences the transport, deposition, and bioaccumulation processes of mercury in the environment (Pacyna et al. 2006; Lindberg et at. 2007).

The majority of mercury emissions originate from point sources located in industrial regions, but the impact of mercury pollution is truly global, affecting the most remote areas of the planet (Jiang, Shi, and Feng 2006; Pacyna et al. 2006). Current research highlights two challenges facing the successful regulation of mercury pollution: the potential for hot spots of mercury contamination near emissions sources, and the ability of emissions to contaminate remote areas far from emissions sources (Fitzgerald et al. 1998). Uncertainty surrounding global versus local deposition makes it difficult to determine source attribution with any certainty and may discourage localized pollution-control efforts (Sullivan et al. 2008).

Mercury in Aquatic Ecosystems

Once mercury is deposited in a water body, bacteria convert inorganic mercury to organic mercury, the most toxic of which is methyl mercury. Methyl mercury can concentrate in aquatic organisms (bioconcentration), accumulate in tissues (bioaccumulation), and increase in concentration up the trophic system (biomagnification) (Fitzgerald and Clarkson 1991; US EPA 1997; Morel, Kraepiel, and Amyot 1998). These biochemical processes occur as mercury cycles through terrestrial and aquatic ecosystems, resulting in harmful mercury levels at the top of the food chain (Morel, Kraepiel, and Amyot 1998; Bjornberg et al. 2003; Sampaio da Silva et al. 2005; Patterson et al 2006). At high levels, mercury may cause abnormal behavior in contaminated organisms, compromising reproductive ability and survival skills (US EPA 1997; Chumchal et al. 2008b). Aquatic environments are more susceptible to mercury contamination because the aquatic trophic system is more complex than the terrestrial trophic system, and exposure occurs through both respiration and consumption of food (Driscoll et al. 2007; Chumchal et al. 2008a). Aquatic ecosystems are the focus of most mercury contamination research for two reasons: the contamination process is exacerbated in aquatic ecosystems, and fish are the vector of human exposure to mercury (Mahaffey, Clickner, and Bodurow 2004; Patterson et al. 2006; US EPA 2006a).

An incomplete understanding of the biochemistry of mercury has impeded the development of adequate policies and regulations. Although the scientific community has made substantial gains toward understanding mercury in the environment, specific factors regulating this process within a water body remain unclear. Site-specific variables are shown to magnify or attenuate mercury contamination within aquatic ecosystems, including the number of trophic levels, amount of mercury deposited in a water body, water pH, dissolved oxygen content, the presence of methylating bacteria, and organic carbon content. Studies suggest that synergistic relationships between these factors are complex and may affect mercury concentrations (Miskimmin et al. 1992; Morel, Kraepiel, and Amyot 1998; Chumchal et al. 2008).

Recent research demonstrates that a lag time of unknown length may exist between the initial input of mercury into an aquatic ecosystem, and subsequent contamination of biota. Paterson et al. (2006) suggests it may take one to three decades for a water body to reach a steady state of mercury concentration, without taking into account the added complexity of continuous but varying rates of mercury deposition. This research suggests that even with emissions controls in place, harmful mercury concentrations in aquatic organisms may persist for decades. While more research is needed to fully understand the behavior of mercury in aquatic ecosystems, environmental managers cannot afford to wait for science to clarify all these uncertainties before acting (Trasande, Landrigan and Schechter 2005).

Human Exposure to Mercury

Human exposure to mercury occurs primarily through the consumption of contaminated fish (Fitzgerald and Clarkson 1991; Mahaffey, Clickner, and Bodurow 2004; Moya 2004; US EPA 2006a). Contaminated fish as a vector of human exposure became clear following an episode of massive mercury contamination during the 1950s in Japan’s Shiranui Sea (Harada 1995). The source of mercury was polluted wastewater discharged from a local industrial plant (Harada 1995). The polluted wastewater contaminated local aquatic organisms and led to extremely high mercury levels among local fish consumers. A neurological disorder, Minamata disease, presented with signs of severely reduced muscular coordination, constricted visual fields, and numbness of the extremities among adults (Harada 1995). Adverse health effects among exposed children and fetuses included mental retardation, disturbance of physical development and nutrition, and deformity of limbs (Harada 1995; Ratcliffe and Swanson 1996). This event demonstrated that mercury accumulates and concentrations are magnified in aquatic ecosystems to levels presenting human health risks (Harada 1995; Clarkson 2002).

Public health concerns in the United States regarding mercury contamination of fish were aroused in 1969 with the discovery of mercury pollution in the Great Lakes system (Clarkson 2002). High levels of mercury in fish from Lake St. Clair led to the closure of the local fishery (US EPA 2009b). The source of mercury pollution was traced to the Dow Chemical Chlor-Alkali Plant in Sarnia, Ontario (Clarkson 2002; US EPA

2009b). Actions taken to reduce mercury input into Lake St. Clair successfully reduced mercury concentrations in fish tissue. This incident became known as the "Mercury Crisis of 1970," and contributed to growing environmental and public health concerns in the United States.

In 1972, another mercury poisoning event occurred in Iraq following the consumption of bread contaminated with a mercury-based fungicide. Amin-Zaki et al. (1974) observed that prenatal exposure to mercury could cause brain damage in the fetus because mercury passes readily from mother to fetus *in utero*. Further research determined the fetal brain is more sensitive to mercury exposure than the adult brain (Bakir et al. 1973; Choi et al. 1978). The Iraq outbreak confirmed neurotoxicity in offspring is the most commonly observed effect of mercury poisoning, and the effect that occurs at the lowest exposures (Ratcliffe and Swanson 1996; US EPA 1997). From this study, the US EPA identified populations with an increased risk for adverse health effects, including: fetuses, developing children, and women of reproductive age (US EPA 1997).

Concern arose that mercury levels in fish most commonly consumed may present a risk of prenatal mercury poisoning (Amin-Zaki et al. 1974; Davidson et al. 1998; Burger 2008). Large epidemiological studies conducted in fish-consuming populations are attempting to determine health effects among children exposed *in utero* (Crump et al. 1998; Davidson et al. 1998; Grandjean et al. 1998). Adverse health effects are wide ranging, the most common occur in high risk populations, and include delayed achievement of developmental milestones, cognitive impairments, and audio-visual and motor function abnormalities (Amin-Zaki et al. 1974; Grandjean et al. 1998; Axelrad et al. 2007). Mercury toxicity among adults occurs at higher levels and interferes with vision, motor function, and memory (Lebel et al. 1998; Castoldi et al. 2003; Yokoo et al. 2003; Oken and Bellinger 2008). Research also indicates mercury is a carcinogen, causes mutations of genetic material (i.e. genotoxicity), and increases the risk of cardiovascular disease (Amin-Zaki et al. 1974; De Flora, Bennicelli, and Bagnasco 1994; Grandjean et al. 1999; Axelrad et al. 2007; Crespo Lopez et al. 2007; Virtanen et al. 2007).

The US EPA estimates that approximately 630,000 infants are born each year with unsafe levels of mercury, constituting a significant societal burden in the form of reduced economic prosperity, and increased health care costs (Rice, Schoeny, and Mahaffey 2003; Sweeney 2006). To adequately protect human health, the US EPA conducted studies to determine a “safe” level of mercury exposure (US EPA 2006a). The US EPA developed a mercury reference dose of 0.1 μg/kg/day; a daily mercury intake likely to be without a significant risk of adverse health effects over a lifetime (US EPA 2001). The US EPA developed this reference dose under the assumption that mercury levels present in the fetus will equal mercury levels present in the mother (Rice, Schoeny, and Mahaffey 2003). However, recent research indicates the ratio of blood-mercury levels between infant and mother is between 1.5 and 2.0, almost double previous estimates (Rice et al. 2003). Clearly, more research is needed to ensure adequate protection of high-risk populations.

In order to reduce human exposure to mercury, the US EPA, the Food and Drug Administration (FDA), and various state agencies issue fish consumption advisories (US EPA 2010i). Fish consumption advisories identify water bodies with elevated levels of contaminants present in consumable fish, and recommend consumption limits for contaminated aquatic organisms (Moya 2004; Burger 2008). The US EPA conducted research to determine a screening value for mercury concentration in fish tissue to identify water bodies that require fish consumption advisories to protect public health (US EPA 2001; Moya 2004). The US EPA recommends state agencies use the mercury screening value of 0.3 mg methyl mercury/kg fish; however, states retain the freedom to set their own screening values for fish consumption advisories (US EPA 2001).

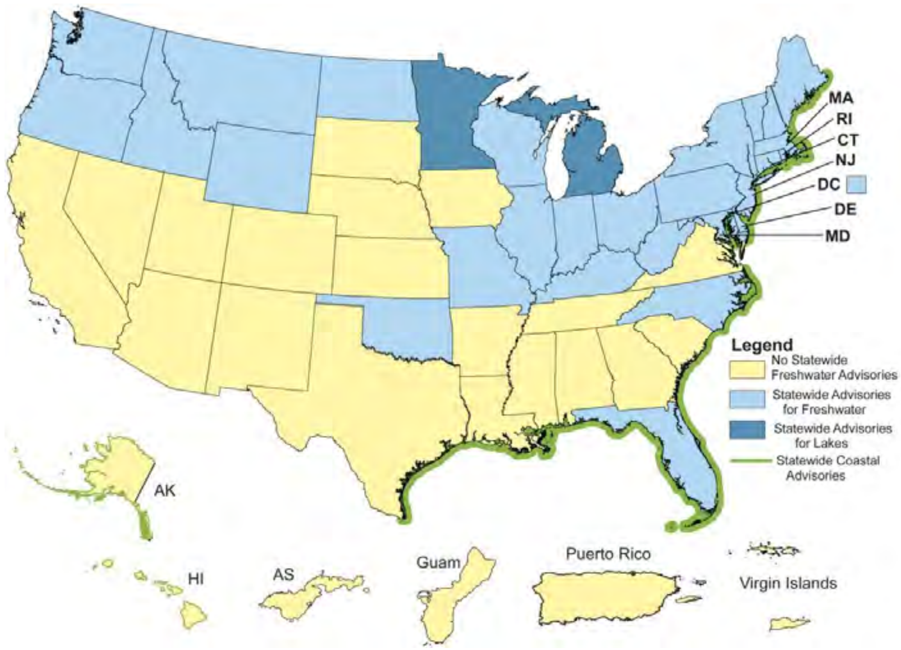

Figure 1. 2008 National Listing of Fish Consumption Advisories (US EPA 2009c)

Table 1. Total advisories, lake acres & river miles under advisory in 2006 & 2008

Contaminant	Number of Advisories		Lake Acres		River Miles	
	2006	2008	2006	2008	2006	2008
Mercury	3,080	3,361	14,177,175	16,808,032	882,963	1,254,893
PCBs	1,023	1,025	4,699,936	6,049,506	132,228	130,248
Chlordane	105	67	847,771	842,913	58,668	54,029
Dioxins	125	123	38,181	35,400	2,315	2,055
DDT	84	76	876,175	876,520	69,021	69,198

(US EPA 2009c)

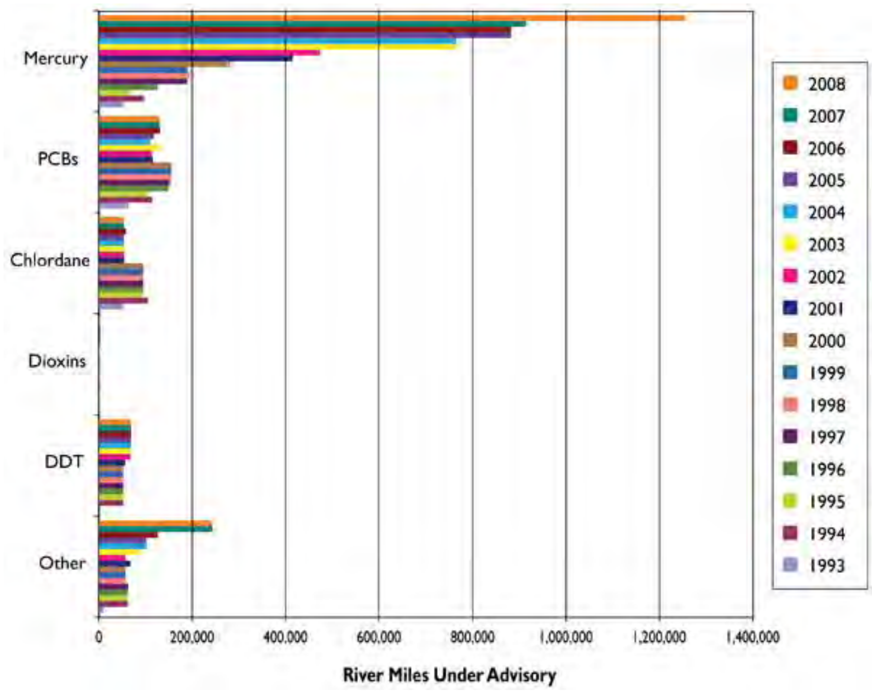

Figure 2. US River Miles under Advisory 1993-2008 (US EPA 2009c)

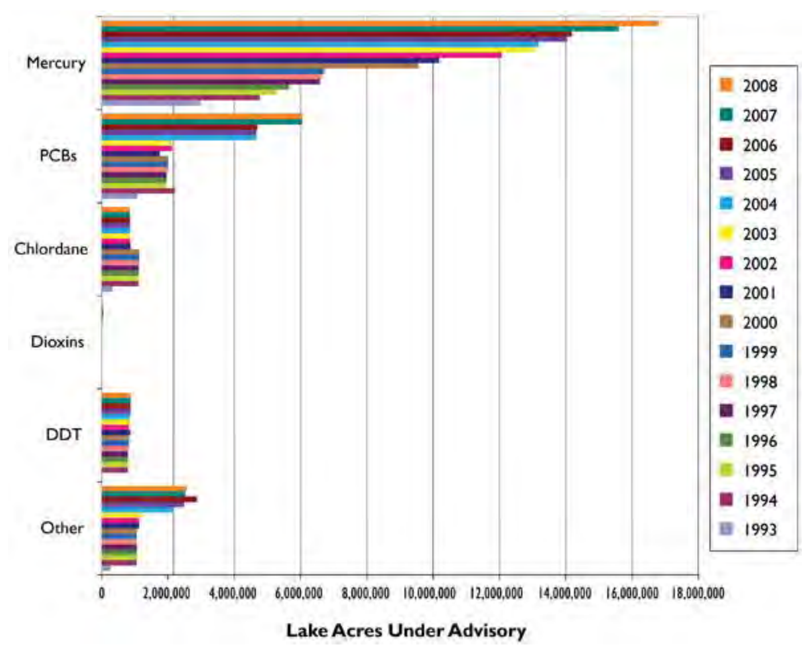

Figure 3. US Lake Acres under Advisory 1993-2008 (US EPA 2009c)

The number of fish consumption advisories nationwide is growing. Figure 1 illustrates the extent of fish consumption advisories nationwide, over half the states in the nation have statewide consumption advisories in effect. In 2008 4,249 water bodies were under consumption advisory, up from 3,852 water bodies in 2006 (US EPA 2009c). Mercury is the most widespread PBT, approximately 80 percent of all fish consumption advisories were issued, at least in part, because of mercury (US EPA 2009c). As of 2008, 50 states, one territory and three tribes issued mercury advisories. Figures 2, 3, and Table 1 illustrate the prevalence of mercury contamination in rivers and lakes nationwide from 1993-2008.

Current Management Framework

Regulation is critical to reducing mercury in the environment, and improving overall social and environmental wellbeing. A clear regulatory structure requiring the reduction of mercury from products and processes provides incentives or mandates for regulated entities to reduce mercury emissions. Federal regulations set the minimum acceptable level of scope and stringency for mercury-related regulations. An explicit regulatory framework aids environmental agencies in enforcement, and encourages compliance among the regulated community (Koski 2007).

Prior to the creation of the US EPA in 1970, the landscape of environmental regulation was highly fragmented and consisted of a patchwork of federal programs focused on various aspects of environmental management. In the early 1970s, the promulgation of the National Environmental Policy Act (NEPA) created not only the foundation of environmental regulation in the United States, but also a platform for the creation of the US EPA (US EPA 1985). Following NEPA, Congress passed two laws to regulate environmental toxics that are relevant to this research, the Clean Air Act of 1970 (CAA) and the Clean Water Act of 1972 (CWA). These two laws create the basic structure for regulating discharges of pollutants into the atmosphere and United States surface waters through establishing minimum standards for pollutants, and requiring polluting industries to comply with these standards (US EPA 1985; US EPA 2010b). The CAA and CWA establish the scope and stringency of mercury regulation in the United States.

The CAA establishes the regulatory framework for protecting and improving the nation's air quality by managing air pollution, primarily from point sources. Originally, the goal of the CAA was to set and attain national ambient air quality standards by 1975; however, this goal was not achieved for many states. The CAA was amended in 1977 to set a new timeline for states to achieve national ambient air quality standards. The 1990 amendments to the CAA address hazardous air pollutants (HAPs), and define technology-based standards for sources of HAPs. Section 112 of the CAA 1990 Amendments identified mercury as a HAP, which requires the US EPA to set emission standards for sources of airborne mercury emissions. The CAA sets mercury emission limits for certain source categories, such as waste incinerators. However, adequate controls are not in place to regulate airborne mercury emissions from all sources. Many mercury-contaminated surface waters are the result of airborne mercury emissions from unregulated or inadequately regulated sources.

The CWA creates the backbone of water management in the United States, and establishes the basic structure for regulating discharges of pollutants into United States surface waters and defining surface water quality standards (SWQS). The CWA gives the US EPA legal authority to set effluent limits for pollutants, including mercury, through technology-based and water quality-based approaches to ensure protection of receiving waters. The CWA requires any entity that discharges pollutants to first obtain a National Pollution Discharge Elimination System (NPDES) permit, otherwise that discharge is considered illegal (US EPA 2009b).

The CWA consists of two approaches to protect and restore the quality of our nation's waters. The first approach, which has been the primary approach employed since the CWA was passed, is a technology-based approach. This technology-based approach is structured around effluent guidelines that rely on available technologies to remove pollutants from waste streams before they are discharged into surface waters. Effluent guidelines are enforced through NPDES permit limits, and only address point source pollution (US EPA 2008).

The second approach is a water quality-based approach, designed to achieve and support the designated uses of a water body, and may result in more stringent NPDES permit limits. Section 303(d) of the CWA is the foundation of the water quality-based approach and serves to link water quality goals to NPDES permit limits by addressing nonpoint sources (NPS) of pollution (US EPA 2008; Figure 4). NPS pollution, unlike point source pollution, is the byproduct of precipitation that moves across the landscape and deposits pollutants that originate from diffuse sources into water bodies (US EPA 2010b).

Water quality management is undergoing significant changes in the United States, as the focus within water quality shifts from point source to nonpoint source (NPS) pollution (Maddock 2004; US EPA 2010a). Although mercury is not a NPS pollutant, a lack of point source regulations on mercury air emissions and water discharges has resulted in states managing mercury through the water quality-based approach, rather than the intended technology-based approach of the CWA and CAA for point source pollution (Smith and Trip 2005; MPCA 2007; NEIWPCC 2007; TCEQ 2009). Regulation of mercury as a NPS pollutant is the result of the US EPA failing to create explicit regulations for sources of mercury emissions. Mercury is managed in a reactive nature by attempting to remediate mercury-contaminated water bodies, rather than regulating mercury at the source.

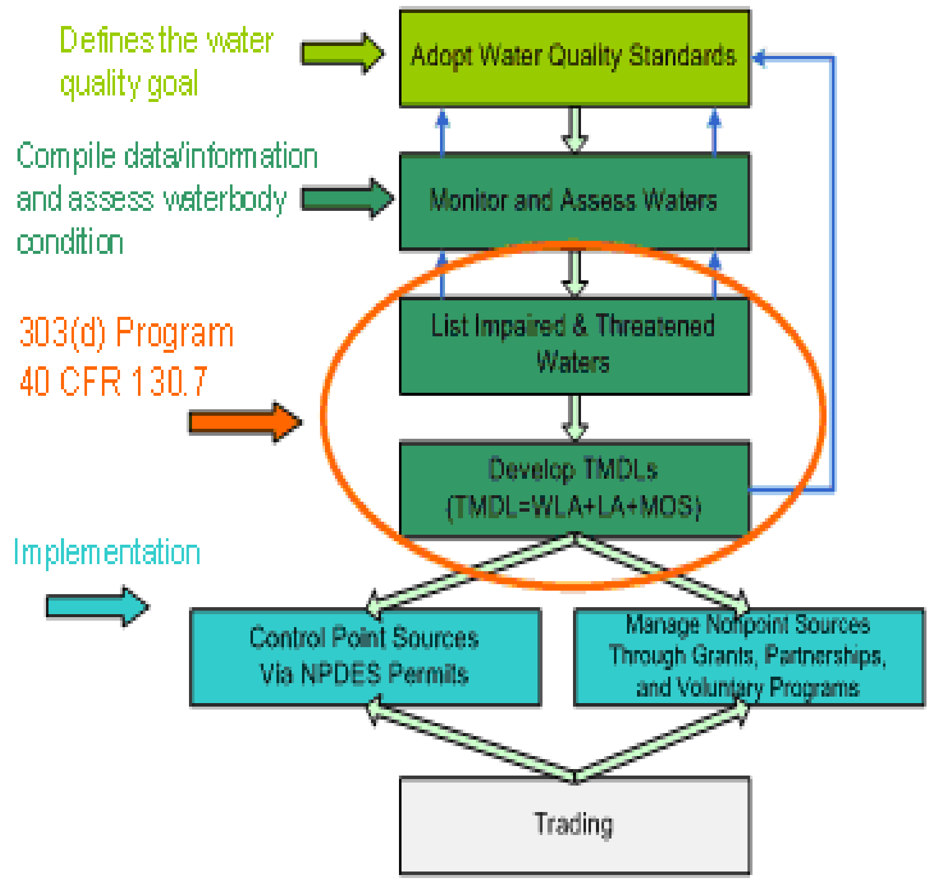

Figure 4. Water Quality Based Approach of the Clean Water Act (US EPA 2008)

Sections 303(d) and 305(b) of the CWA require states to conduct a biannual water quality assessment and to report the condition of their waters to the US EPA, Congress and the public (US EPA 2008). Section 303(d) requires each state to compile a list of impaired waters, commonly known as the 303(d) List, which identifies water bodies where pollution concentrations violate SWQS (Smith et al. 2001; US EPA 2010d). 303(d) listed segments remain on the list until the impairment is addressed through a total maximum daily load (TMDL) process, or subsequent water quality monitoring indicates the water body is no longer in violation of SWQS. Following monitoring and assessment of waters, states are required to construct and implement management plans to ensure water bodies meet SWQS (US EPA 2010d).

Section 305(b) requires a biannual submission of the National Water Quality Inventory Report to Congress, commonly referred to as the 305(b) Report (US EPA 2009d). The 305(b) Report is the primary mechanism states use to inform Congress and the public of overall water quality conditions (US EPA 2009d). US EPA encourages, but does not require, states to submit the 303(d) and 305(b) reports in an integrated water quality assessment report that includes a description of any changes in impaired waters and state programs to address impairments. This data is available through the US EPA Water Quality Assessment and Total Maximum Daily Loads Information (ATTAINS) online database, and through state agency websites (US EPA 2010c). This assessment, monitoring, and reporting requirement of the CWA ensures mercury pollution, among other water quality concerns, remains a priority for all United States surface waters, regardless of geographic location, political environment, and regulatory jurisdiction.

During the biannual water quality assessment process, states must categorize all assessed waters into one of five categories defined in the CWA. Waters listed in category one support all designated uses, and are considered to be attaining all applicable water quality standards (US EPA 2010d). Category two waters meet some SWQS, but insufficient data exists to determine attainment of other SWQS (US EPA 2010d). Water bodies placed in category three have insufficient data to determine water quality attainment (US EPA 2010d). Category four waters are impaired waters that a TMDL has either been approved by the US EPA (category four a), or a TMDL is not needed because attainment is expected to be achieved through other pollution controls (category four b) (US EPA 2010d). Water bodies placed in category five are impaired for one or more SWQS, and may require a TMDL. Category five waters, historically known as the 303(d) List, are those waters described as impaired for purposes of biannual water quality reporting (US EPA 2010d).

States have some discretion regarding water body classification; however, the US EPA must approve the classification of all surface waters (US EPA 2010b). If water quality data does not support the category assigned to a water body, the US EPA has the authority to place that water body into the category deemed appropriate by the Agency (US EPA 2010d). In addition, water bodies are shuffled among categories during each two-year listing period. Water bodies that were previously impaired, but now meet all SWQS are “delisted” (US EPA 2010b). Water bodies that are impaired and have an approved TMDL are moved from category five to category four a.

This process of re-classifying water bodies may change the perception of water quality impairments in a state (Keller and Cavallaro 2008). For example, Massachusetts currently collaborated with seven states in the northeastern United States to develop a regional mercury TMDL for all impaired freshwater bodies within the region (NEIWPCC 2007). Upon US EPA approval of the regional TMDL, Massachusetts decided to reclassify these category five water bodies under category four a. In 2008, Massachusetts reported no mercury impaired waters; however, attainment will likely take years and many state waters still exceed mercury SWQS (MA IR 2008).

In compliance with Section 303(d) of the CWA, the US EPA has outlined the TMDL process (US EPA 2007; US EPA 2010b). The TMDL process is at the core of the water quality-based approach of the CWA and addresses NPS pollutants, including mercury. A TMDL is a calculation of the maximum amount of a given pollutant a specific water body can absorb and still meet SWQS (US EPA 2007). Even though conventional water pollutants are screened through the TMDL process, the process is criticized as not adequately protecting ecosystems from water pollutants, particularly PBT pollutants such as mercury (US EPA 2007).

Critics argue that managing a polluted water body through a TMDL process is ineffective because an accidental pollutant discharge or a large rainfall event may cause the water body to exceed SWQS (MPCA 2007). In addition, the protection of surface waters through the TMDL process requires precise scientific data often not available regarding pollution origination and movement within the watershed. The source of mercury pollution is not easily identified in waters impaired by atmospheric deposition of mercury, further complicating mitigation (MPCA 2007; TCEQ 2009). Without clear science on mercury emissions and transport within a watershed, identifying the cause of impaired water quality is difficult. TMDL development for mercury polluted waters focuses on the process by which an acceptable level of pollution for a given water body is determined, and a corresponding quantity of mercury a water body could absorb before mercury concentration in fish tissues exceeds safe levels (US EPA 2007; TCEQ 2009). Determining safe levels of mercury requires unique characterizations for each water body; this is a time consuming, complex, and costly process with wide margins of error.

Remediating impaired water bodies through the TMDL process is a complex and potentially expensive process. The TMDL process dominates current water policy debates (Smith et al. 2001; NEIWPCC 2007; US EPA 2007). Policy reviews, lawsuits, regulations, and political interest have focused on a previously obscure provision of the CWA (Smith et al. 2001; Keller and Cavallaro 2008; US EPA 2009a). Section 303(d) gained current prominence in the 1980s when environmental advocacy groups began suing states and the US EPA for not enforcing this provision of the CWA (Smith et al. 2001; Maddock 2004; US EPA 2009e).

The CAA and the CWA are integral to managing mercury in the environment because together these two Acts outline the minimum scope and stringency of mercury regulations in the United States. The CAA and CWA establish the scope of mercury regulations by identifying various regulated sources of mercury discharges into surface waters and airborne mercury emissions. The CAA and CWA define the stringency of mercury regulations by setting numerical limits on mercury discharges into surface waters and airborne emissions of mercury. Together, the CAA and CWA comprise the federal regulatory landscape of mercury management.

The CAA and CWA are important to the future of mercury management because together these two laws create an existing regulatory framework within which to expand the scope of federal regulations on sources of mercury pollution and the stringency of regulations on various sources of mercury pollution. The assessment, monitoring, and reporting requirements of the CWA enable state and federal governments to prioritize the hazard of mercury in aquatic environments by state or region. In addition, the TMDL process detailed in the CWA represents the most successful management tool to reduce mercury in surface waters. The TMDL process provides a tool for states to remediate mercury-contaminated water bodies and to prevent further mercury pollution of water bodies by identifying sources of mercury within the watershed.

The CAA and CWA are enforced through state environmental agencies, and it is at the state scale that environmental regulations are interpreted, negotiated, and implemented (Maddock 2004; US EPA 2010b; US EPA 2010e). Individual states have unique geographic characteristics, economies, and political structures, resulting in variable regulatory landscapes across the nation. Current management strategies for mercury contaminated water bodies are limited by a high degree of uncertainty, incomplete data, and the lack of a standardized data collection, management, and reporting framework (Keller and Cavallaro 2008).

CHAPTER III

LITERATURE REVIEW

This research develops the theory of regulatory landscapes as a conceptual tool to aid in understanding mercury management across the northeastern United States. This research explores geographic aspects of mercury regulation and management, and examines the variations among state regulatory landscapes. Environmental regulation and policy represents a series of interconnected political preferences and social values of a place. The way policy makers view a problem is reflected in the language and specific provisions of a regulation or policy.

Four general bodies of literature are relevant, and serve to justify the methodology of this research. A small literature addresses the conceptualization of geographic phenomena through regulatory landscapes. Another discussion explores the importance of scale in determining the effectiveness of environmental regulations. In addition, conflict surrounding environmental regulations can have the effect of fragmenting the regulatory landscape. A larger geographic literature is present that examines environmental policy and regulation in a geographic perspective. Each of these bodies of literature necessitates further exploration within the context of this research.

Understanding Regulatory Landscapes

Scholars from several disciplines use the term “regulatory landscape” to illustrate patterns of legislation and regulation, similar to the way one would describe features and elements of a physical landscape (Hudson 1998; Wider and Scanlan 2003; Reisman and Wehland 2004; Santoianni et al. 2008). One scholar has addressed the regulatory landscape explicitly in geographic terms (Hudson 1998). A variety of other disciplines have used the term regulatory landscape to describe how laws and regulations are expected to change and affect certain social and economic sectors of society, but this body of literature offers little insight into the geography of regulatory landscapes (Wider and Scanlan 2003; Reisman and Wehland 2004).

Used to explore the variance of government action, the concept of a regulatory landscape encourages the geographic description and understanding of environmental policy and management across space (Hudson 1998; Koski 2007). The conceptualization of regulatory landscapes serves as a tool to aid in understanding regulatory and legislative processes across space. Regulatory landscapes, similar to physical landscapes, are composed of people and places. A regulatory landscape is comprised of the interactions between people and landscapes; people reshape the landscape, and at the same time, the landscape influences the people (Hudson 1998).

A regulatory landscape is ever-changing, uneven, and most importantly, socially constructed (Burch and Denmark 1997). Regulatory landscapes are a result of the physical landscape and the social organization of space and processes within a geographic region (Hudson 1998; Marston 2000). The social construction of regulatory landscapes is important to this research because social values and priorities shape the regulatory landscape of a place (Agnew 1997; Marston 2000). Social construction of regulatory landscapes applies to this research because social values and societal priorities regarding environmental management, toxics in the environment, and human health define mercury regulations across the northeastern United States. The regulatory landscape of mercury management is dynamic and uneven across the region and this variability is partly the result of social phenomena.

This research examines the dynamic and socially constructed regulatory landscape of mercury management in the northeastern United States. As social, economic, and environmental components of the landscape change, the larger regulatory landscape also changes. The social construction of regulatory landscapes is evident in this research as each state creates a unique framework within which to manage mercury in the environment. Each state structures mercury regulations in a manner that incorporates economic and environmental realities as well as societal priorities and values within the state.

Importance of Scale

Regulatory landscapes are nested within a geographic scale, which is also socially constructed (Agnew 1997; Hudson 1998; Marston 2000). Scale is important because scale is an expression of boundaries, and boundaries are an expression of the power structure (Hudson 1998; Marston 2000). The scale at which regulation is structured is crucial and depends upon technological advances and political decisions regarding the most effective geographic scale for regulation of the commodities in question (Agnew 1997; Norman and Bakker 2009). In the case of mercury emissions, the commodity flows across geographic boundaries while the rules regulating these emissions do not (Hudson 1998; US EPA 2007). A mismatch is present in the United States between the scale of mercury emissions and the scale of regulations addressing mercury emissions (Hudson 1998). These disparate scales will be difficult to rectify without additional research into the current geography of mercury regulation.

The examination of environmental challenges in the context of a regulatory landscape raises debate regarding whether government regulation is most effective at a centralized (i.e. regulatory harmonization) or decentralized scale (i.e. regulatory fragmentation) (von der Heidt et al. 2008). In the United States, environmental regulation at the sub-national scale is decentralized, and has led to an increase in citizen participation in environmental governance of water resources (Day 2004; Norman and Bakker 2009). In addition, the scale and structure of the regulatory landscape influences alliances and coalitions among stakeholders, ultimately defining the power structure within these stakeholder groups (Maddock 2004). The power structure within states related to environmental mercury is relevant because this power structure affects the formulation and implementation of regulations.

Regulatory overlap, contradiction between regulatory scales, and tension among governmental agencies and organizations creates considerable barriers for effective regulatory programs (von der Heidt et al. 2008). Scales of regulation influence the effectiveness of regulation, and the nature in which stakeholders become involved and form coalitions around common ideas (Agnew 1997; Hudson 1998; Maddock 2004; von der Heidt et al. 2008; Norman and Bakker 2009). The use of regulation to address environmental impacts resulting from industrial processes is examined within the multi-jurisdictional government system of Australia (von der Heidt et. al. 2008). Difficulties resulting from regulation within a multi-jurisdictional government include policy negotiation and competing priorities occurring between and across scales of government (Maddock 2004; Hardy and Koontz 2008; von der Heidt et al. 2008).

In the United States, environmental regulation occurs within a multi-jurisdictional system of government in which the federal government establishes minimum requirements for regulation, and state governments are responsible for implementation of federal regulations. These two scales of regulation may foster a disjointed and inconsistent regulatory landscape, or the two scales may work together to create a smooth and complimentary regulatory landscape.

Conflict Fragments the Regulatory Landscape

The fragmentation of traditional stakeholder coalitions causes new interest groups to unite into coalitions with a common policy agenda, and to change the distribution of political power and encourage environmental regulatory reform (Hajer 1995; Maddock 2004). The decentralization of regulation, coupled with an increase in citizen participation, is resulting in a new regulatory landscape for environmental management (Maddock 2004). Water quality conflicts are fragmenting power structures that previously dominated environmental regulation and new stakeholder collaborations are emerging (Maddock 2004). The TMDL process in Ohio exemplified the narratives nested within stakeholder groups and the influence of these narratives on the regulatory landscape of environmental policy (Maddock 2004). Collaboration is crucial to environmental regulation, particularly when the environmental concern in question is elusive and management programs lack adequate funding.

An examination of the regulatory landscape that influences energy production from animal waste describes changes within the regulatory landscape of animal waste in the context of federal laws, state-level programs, and economic incentives (Santoianni et a. 2008). The author offers a geographic explanation for the changing regulatory landscape; the size and distribution of farms have necessitated a change in regulation in order to control pollution. The geographic distribution of confined animal feeding operations caused an increase in issue-salience regarding animal waste impacts on the environment. The authors discuss how the interaction of various regulatory approaches influences the evolution of a management framework by identifying alternative approaches to animal waste. As water quality standards evolve, waste management approaches must also evolve, and the regulatory framework is largely responsible for the rate of progress.

The idea that issue-salience is a dynamic process that can undergo dramatic change in the face of environmental impacts from certain regulated or unregulated activities has informed the methodology of this research. The issue-salience of mercury has undergone significant changes since mercury became a major water quality concern. Recent research has thrust mercury hazards into the forefront of the water management framework, and many states are grappling with devising an appropriate regulatory landscape to respond to these concerns.

Examining Environmental Regulations across Space

Scholars examine the policy design of environmental regulations on state, regional, and national scales (Karr 1990; Maddock 2004; Koski 2007; Hardy and Koontz 2008). The design of environmental policy can affect the motivations of regulated entities, the discretion governments give enforcement agents, and the level of commitment to solving environmental problems. In many cases, the federal government provides a regulatory foundation dictated in the code of federal regulations, and states exercise discretion within specified areas of environmental regulations (Koski 2007). The discretion exercised by states is evident by examining the scope and stringency of regulatory language generated at the state level (Koski 2007). The methodology of this research recognizes the value of scope and stringency in characterizing state regulatory landscapes.

State-level management programs are increasingly addressing NPS pollution, and wrestling with the science and politics of regulating diffuse pollution sources (Maddock 2004; MPCA 2007; US EPA 2010a). Lessons drawn from NPS pollution management are relevant to environmental mercury because NPS strategies primarily dictate mercury management in the United States. NPS pollution management emphasizes the collaborative efforts between state and federal governments. In regards to NPS pollution, success hinges on the availability of resources, and the quality of communication between regulatory scales (Hardy and Koontz 2008). In this study, the authors identify the importance of collaboration to implement effective water resource regulations and management strategies.

The fragmented approach to environmental legislation and subsequent regulations within the United States are reactive in nature, addressing problems only after degradation is obvious (Karr 1990). This reactive nature is clear in water quality regulations of the CWA (US EPA 2007; US EPA 2010b). Water quality management and regulation has focused on point source pollution with an emphasis on command-and-control technology and developing priority ranked lists of pollutants in need of regulation (Karr 1990). Current water quality management attempts are a "folly of trying to restore water resources with single-minded approaches, the dominant theme of agencies dealing with the nation's waters" (Karr 1990, 246).

Water management is historically an economic and environmental discipline, but there is growing recognition that ultimately the political system greatly influences the selection and implementation of water policies (Jasanoff 1990; Maddock 2004; US EPA 2007). Debate regarding what constitutes sound scientific practice is central to the controversy over equitable and effective environmental regulations (Maddock 2004). Often, diverse stakeholders have difficulty navigating the variety of viewpoints inherent in environmental regulation, and therefore all stakeholders claim to have sound science supporting their position. However, the uncertain science concerning NPS water pollution complicates the progress of effective environmental regulation (Jasanoff 1990; Maddock 2004). This is particularly true of mercury regulation, characterized by extensive debate regarding the behavior of mercury in the environment and little attention focused on effective regulatory structures.

The above discussion exhibits the four attributes central to the measurement of a regulatory landscape: issue-salience, collaboration, and scope and stringency of regulations. Issue-salience is important because it is a measure of the political will and financial resources available to address environmental concerns. Collaboration is crucial to the regulatory landscape because it signals a wider capacity for acceptance and action regarding environmental challenges. The scope and stringency of regulations are critical to the methodology of this research because together these two variables allow a systematic examination of the “teeth” or “meat” and the breadth of environmental regulations. Conclusions drawn from the research outlined in this section justify measuring the regulatory landscape of mercury management using these four attributes that are extracted from the data.

CHAPTER IV

METHODOLOGY

Study Area

Effective state-level regulation and management are critical in order to protect human health and the integrity of water resources from harmful levels of mercury. The need to examine state-level regulation of mercury in the environment is evidenced by the fragmented regulatory landscape of mercury management across the United States. This research focuses on the northeastern United States, composed of US EPA regions One, Two, Three, and Five (Figure 5). These four US EPA regions encompass twenty states, extending from the industrial landscapes of Ohio, Pennsylvania, and Michigan, to regions of rural activities exemplified by Maine and Minnesota. Ecologically sensitive water resources are widespread in this region, and include the Great Lakes, the Chesapeake Bay, and other productive estuaries.

A pilot study was conducted to explore the geographic variability of mercury regulation and management across the United States and to create the rubric used to collect data from each state. Five states were chosen to represent regions of the United States: California, Florida, Michigan, Pennsylvania, and Texas were analyzed for patterns in management and data availability to determine the most appropriate regional focus. A content analysis of state-level regulations addressing mercury water discharges and air emissions was conducted to determine issue-salience and to characterize the current regulatory landscape. Historically, Michigan and Pennsylvania, and the northeastern United States as a whole, have had experience with the management of environmental pollution generated by decades of industrial production. Michigan and Pennsylvania responded to mercury contamination similarly by constructing a state-level regulatory framework to reduce mercury in the environment (Table 2). The northeastern United States has a longer history of industrial pollution and more experience with managing mercury in the environment.

The study area was selected to coincide with the geographic boundaries of US EPA planning regions as well as to exploit data availability and the historic experience of regions that have managed the environment impacts of industry. US EPA modeling indicates a significant geographic variability in domestic mercury pollution across the United States. Domestic mercury emissions are a more significant contribution to mercury deposition in the northeastern United States, while global emissions are more significant in the western United States (US EPA 2006a). Because domestic mercury emissions and deposition are more clearly linked to mercury pollution in the northeastern United States, this region better fit the focus of this research.

The northeastern United States is an exceptionally compelling place to study environmental toxics and regulation because of the industrial history of the region. The long shadow of industrial manufacturing and environmental toxics cast over the region is evident at all scales. The northeastern United States is known as the manufacturing belt because of the concentration of industry along the northeastern seaboard and the eastern portion of the Midwest (Krugman 1991). This concentration of industry and environmental toxics affects the physical and social landscape of the region (Colten 1994). The northeastern United States is the front line for regulations addressing environmental toxics. The concentration of population and industry in this region of the United States has provided many lessons for the regulation of environmental toxics and the cooperation between industry and government to protect public health.

The population and economy of the northeastern United States changed significantly over the last century (Driscoll et al. 2003). Following the Industrial Revolution, the region sustained rapid urban population and industrial growth, and now receives large amounts of mercury deposition from a variety of sources within the urban landscape. These mercury inputs onto the physical landscape have led to a variety of environmental problems and have sparked a series of regulations and management approaches to address public health impacts.

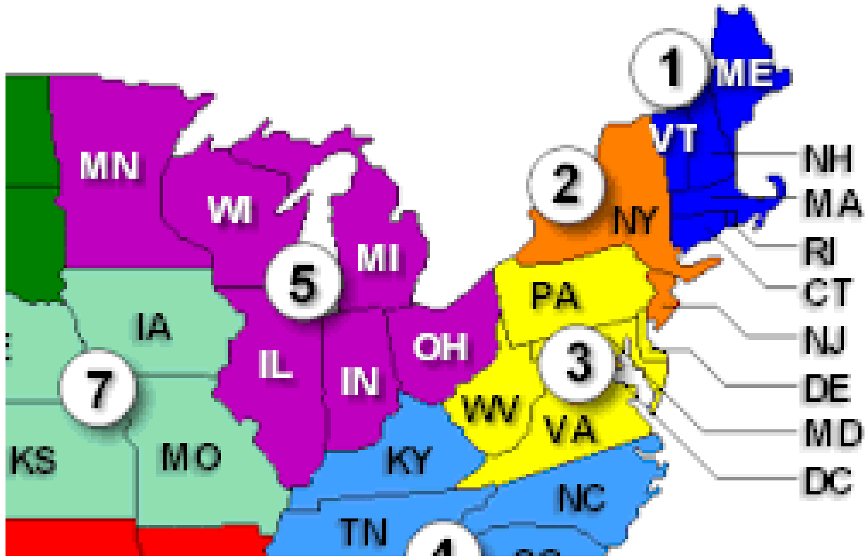

Figure 5. US EPA Planning Regions (US EPA 2006b)

Table 2. Pilot Study Data

State	Surface Water Quality Standard for mercury in fish tissue	303(d) and 305(b) Reporting status to EPA	State Regulation on Mercury Emissions from Coal Power Plants	State/Regional Mercury Management Programs	Agency Research on Mercury in the Environment	Extent of mercury contamination in state water bodies
MI	0.35 mg/kg	reported 303(d) and 305(b) List for last 3 assessment cycles	Rules for coal plants finalized Oct. 2009. By 2015 coal EGUs must meet 90% reduction of Hg emissions	Mercury Strategy Workgroup addresses pollution through air emissions, water discharges, and waste from mercury-containing products	Jan 2008 MDEQ published Hg Strategy Staff Report to examine how to reduce anthropogenic Hg pollution, identified 67 reccommended actions to eliminate anthropogenic Hg release and use	1,069 water bodies
PA	0.13 mg/kg triggers consumption advisory; 1.9 mg/kg results in a consumption ban	most recent 303(d) list from 2004; most recent 305(b) list from 2006	Passed Mercury Reduction Rule in 2007 to reduce emissions 90% by 2015; January 2009 PA court declared rule invalid and unenforceable	none	none	112 water bodies

Data

US EPA, FDA, United States Geological Survey (USGS), and state health and environmental agencies are responsible for the collection, analysis, and publication of mercury data. Currently, no standardized procedures exist for collecting and analyzing mercury samples, making it difficult to compare data between the various state and federal agencies responsible for mercury monitoring. Although the US EPA has released guidance documents encouraging the use of certain data analysis methods and data reporting procedures, inconsistencies exist, compromising the integrity of national mercury datasets. Given these limitations, this research was modified to rely less on quantitative data characterizing mercury contamination and more on qualitative data describing management strategies, regulatory programs, and state efforts to reduce mercury in the environment.

Table 3. Data Collection Variables and Regulatory Landscape Attributes

State Variables	Regional Organizations	State Mercury Management Air Emissions	State Mercury Management in the Waste Stream	State Hg Management Water Discharges	Mercury Surface Water Quality Standards	State Research on Mercury in the Environment	Extent of Mercury Contamination
Regulatory Landscape Attributes	collaboration	Waste Incineration = stringency; Coal = scope & stringency	Scope & stringency	Dental discharges = scope & stringency	stringency	Issue-salience	Issue-salience

This research focuses on anthropogenic mercury in the environment. Regulations are organized by three pathways of environmental contamination: air, water, and waste. Variables collected to measure attributes of the regulatory landscape are listed in Table 3 and include: regional organizations, mercury management programs, state regulations on mercury emitted from air, water, and waste sectors, mercury SWQS, agency research on environmental mercury, and the extent of mercury contamination. The variables collected translate into attributes of state regulatory landscapes (Table 3).

Air regulations examined include mercury emissions from coal-fired power plants, municipal waste incinerators, and hospital/medical/infectious waste (HMIW) incinerators. Regulations regarding mercury water discharges examined include mercury discharges from dental facilities into POTWs, and SWQS for mercury. State regulations limiting mercury discharges from dental facilities are measured by the efficiency of mercury removed from wastewater prior to discharge. Data regarding state regulations on air emissions and water discharges of mercury were collected from state administrative codes published on state environmental agency websites.

Mercury surface water quality criteria are expressed as either micrograms per liter (µg/L) of mercury in the water column, or parts per million (ppm) of mercury in fish tissue. State SWQS were collected from environmental agency websites. Regulations focused on mercury in the waste stream examined in this study include ban on sale or distribution of mercury-containing products, recycling/collection/disposal of mercury-containing products, ban on educational use of mercury in primary and secondary schools, and labeling requirements for mercury-containing products. These data were collected from state administrative codes, and state environmental agency websites.

In order to capture the extent of mercury contamination and the relevance of this pollutant within the larger water quality management framework of a given state, data were collected that describe mercury contamination of several categories of water bodies (i.e. rivers and streams, lakes and reservoirs, bays and estuaries, ocean, and Great Lakes waters). The extent of mercury contamination for a water body category within each state is measured by dividing the area (miles or acres) of mercury-contaminated waters by the total area of waters in that category. These data were collected from the US EPA ATTAINS database, and state water quality assessment reports. US EPA developed the ATTAINS database to facilitate the display of water quality data, and to support state reporting of water quality conditions (US EPA 2010c).

In addition to variables measuring mercury in the environment, data detailing issue-salience and collaboration within state mercury management programs were also collected. Management data collected include regional organizations involved in mercury management, and research conducted by state environmental agencies. These data serve to express the amount of collaboration among states, as well as the quantity and quality of research regarding mercury in the environment. These data are also an indicator of the issue-salience of mercury within state environmental agencies. Data regarding regional organization membership were collected from state agency websites, TMDL documents, published findings of mercury research, and state water quality assessment reports.

Methods

State variability in monitoring procedures, standards, and data management results in a fragmented regulatory landscape across the United States. Variability in the regulatory landscape is problematic for state, regional, and national efforts to reduce mercury in the environment. Inconsistencies in the regulatory landscape result in an uneven application of mitigation and management strategies necessary to protect public health from mercury hazards. A number of studies have examined mercury in the environment; however, most focused on adverse human health effects and the economic impacts of regulating or not regulating mercury in the environment. These studies offer insight into the societal costs and benefits of regulating mercury. This study takes a different approach by examining state and regional efforts to manage and mitigate mercury in the environment; and seeks to offer insight into the geographic variability of environmental mercury management in the northeastern United States.

Similar to Hardy and Koontz (2008), this research characterizes state-level management programs focused on mercury pollution reduction. A review of the documents regarding mercury management and regulatory programs is conducted to understand the variation of issue-salience, collaboration, and scope and stringency in mercury regulations across the northeastern United States. Similar to Bester et al. (2008), the regulatory landscape of each state is characterized by the sources of mercury emissions, prevalence of mercury contamination of state surface waters, and strategies used to address public health risks associated with environmental mercury.

This research examines the regulatory landscape of mercury management in the northeastern United States by describing the following attributes: issue-salience of environmental mercury, collaboration with regional organizations, and the stringency and scope of mercury regulations at the state level. Issue salience is measured through three variables: state and regional mercury management programs, agency research regarding mercury in the environment, and the extent of mercury contamination within state waters. Collaboration is measured by membership in regional organizations addressing environmental mercury. The exact language used to limit industrial entities involved with environmental mercury is, ultimately, what measures the stringency of mercury regulations. In this research, stringency is measured through four variables: the numerical value of state SWQS and the required reduction in mercury emissions (usually expressed as a percent) from waste incinerators, coal power plants, and dental facilities. The number of regulated activities associated with environmental mercury measures the scope of mercury regulations. The number of mercury emitting sectors regulated by each state, in excess of federal requirements, describes regulatory scope. Mercury polluting sectors addressed in this research include coal power plants, dental facilities, and the solid waste stream.

For each state, a description of current regulations and management programs is included. An extensive review of relevant state, regional, and federal agencies and current research and management programs within these agencies was conducted for each state. These programs are examined to determine the level of mercury management present in each state, and to identify technical guidance documents, rules, and regulations limiting mercury in the environment. The documents are analyzed to determine current management frameworks and regulatory actions occurring in each state. The purpose of this process is to characterize the regulatory landscape of mercury management in each state and to determine the scope and stringency of mercury regulations in each state, similar to Koski (2007).

This research is qualitative in nature because the data available are not conducive to a quantitative study. Since no quantitative method or tool was available to measure state regulatory landscapes, this study develops a qualitative method. This research relies on collecting regulatory and management data from a variety of state, regional, and federal documents and mercury management programs to measure the scope and stringency of state regulatory landscapes. The data were extracted from documents through a content analysis, and keyword search. The instrument used to collect these data is a structured rubric consisting of an excel database and narratives that detail state regulatory and management programs relevant to environmental mercury (Table 3). The pilot study field-tested this data collection rubric, and provided clarity to determine the variables needed to characterize state regulatory landscapes.

Once the analytical instrument was developed, state regulations and management data were complied by searching state agency websites, regional organization websites, state administrative codes, TMDL documents, water quality assessment reports, research findings, SWQS, and fish consumption advisories and bans. A content analysis was conducted on these documents to extract data regarding issue-salience, collaboration, and the scope and stringency of state regulations. The content analysis focused on extracting data regarding mercury reduction programs and goals, state and regional management programs, extent of mercury contamination within state surface waters, state regulations on environmental mercury in air, water, and waste, and the extent of state collaboration with regional organizations (Table 3).

CHAPTER V

RESULTS

The regulatory landscape of mercury management across the northeastern United States is dynamic and highly fragmented. Federal regulations are in place that limit mercury emissions from waste incinerators, but federal leadership is absent for mercury emitted from coal power plants, and water discharges from dental facilities. Certain states are defining their own regulatory landscape in the absence of federal action by regulating mercury in the waste stream, water discharges, and atmospheric sources of mercury emissions. Other states are more passive, awaiting federal action to adopt an existing regulatory landscape rather than creating their own.

Among the twenty northeastern states in this study, a range of regulatory approaches to mercury management is present. Some states have developed a comprehensive regulatory landscape for mercury management by addressing mercury air emissions, mercury water discharges, and mercury in the waste stream. Other states have a highly fragmented regulatory landscape with minimal mercury management programs in all three media.

Federal regulations do not currently exist for mercury emissions from coal power plants, or mercury discharges from dental facilities into POTWs. Where federal regulations are absent, some states are regulating mercury in the environment by targeting certain sources of mercury emissions. This source-based approach at the state-level causes a variable regulatory landscape as states and regions pass rules and regulations in the absence of comprehensive federal action. This variable regulatory landscape creates confusion among the public that sometimes receives multiple, and occasionally contradictory, public health messages, particularly relating to water bodies spanning state boundaries.

Regulatory Landscape of Mercury in the Waste Stream

Within the study area, management of mercury in the waste stream is divided into four categories: ban on the sale and distribution of mercury-containing products, mercury collection, recycling, and disposal programs, ban on the educational use of mercury in primary and secondary schools, and labeling requirements for mercury-containing products. Most states participate in at least one of these programs (Figures 6, 7, 8, and 9). The District of Columbia and West Virginia do not participate in any management programs to reduce mercury in the waste stream. Maryland, New York, and Vermont have passed regulations that address all four categories of mercury in the waste stream (Table 4).

Among these four categories, mercury collection, recycling, and disposal programs are the most prevalent in the region, with eighteen states incorporating this into their regulatory landscape. State programs banning the sale and distribution of mercury-containing products are present in fifteen of the twenty northeastern states. State-level regulations banning the educational use of mercury in primary and secondary schools are present in nine states within the region. Lowest participation is present in the category of labeling of mercury-containing products; only six states in the northeastern United States have regulations regarding this category.

The most prevalent waste regulations are collection, recycling, and disposal programs and those banning the sale and distribution of mercury-containing products because these regulations effectively remove mercury from the waste incineration process, thus reducing mercury air emissions. Labeling requirements and regulations banning the educational use of mercury in primary and secondary schools are less prevalent because these uses of mercury do not clearly translate into mercury air emissions.

Table 4. State Regulations on Mercury-Containing Products in the Waste Stream

State	Ban on Sale & Distribution of Mercury-Containing Products	Mercury Collection, Recycling or Disposal Programs	Ban on Mercury in Primary & Secondary Schools	Mercury Labeling Requirements
CT	Y	Y	N	Y
DC	N	N	N	N
DE	N	Y	N	N
IL	Y	Y	Y	N
IN	Y	Y	N	N
MA	Y	Y	Y	N
MD	Y	N	Y	Y
ME	Y	Y	N	Y
MI	Y	Y	Y	N
MN	Y	Y	N	N
NH	Y	Y	Y	N
NJ	Y	N	N	N
NY	Y	Y	Y	Y
OH	Y	Y	Y	N
PA	Y	Y	N	N
RI	Y	Y	N	Y
VA	N	Y	N	N
VT	Y	Y	Y	Y
WI	N	Y	Y	N
WV	N	N	N	N

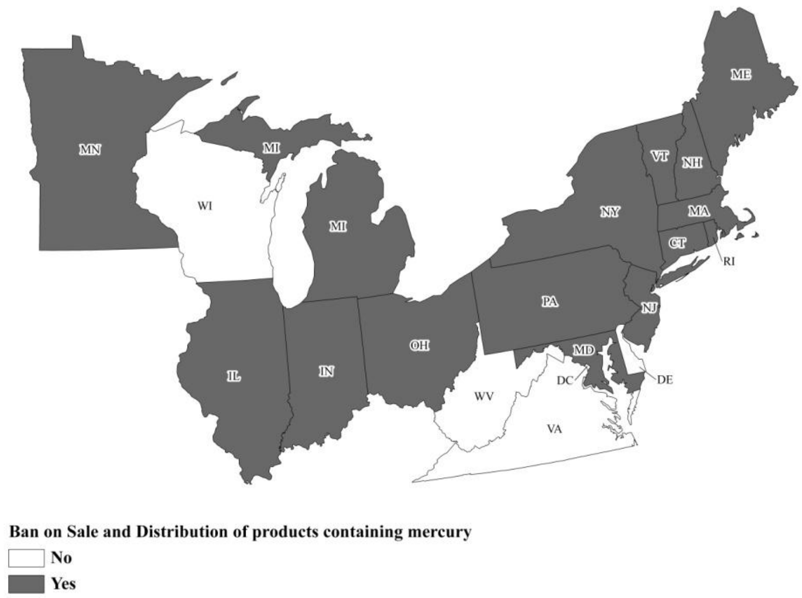

Figure 6. State Regulations Banning Sale & Distribution of Mercury-Containing Products

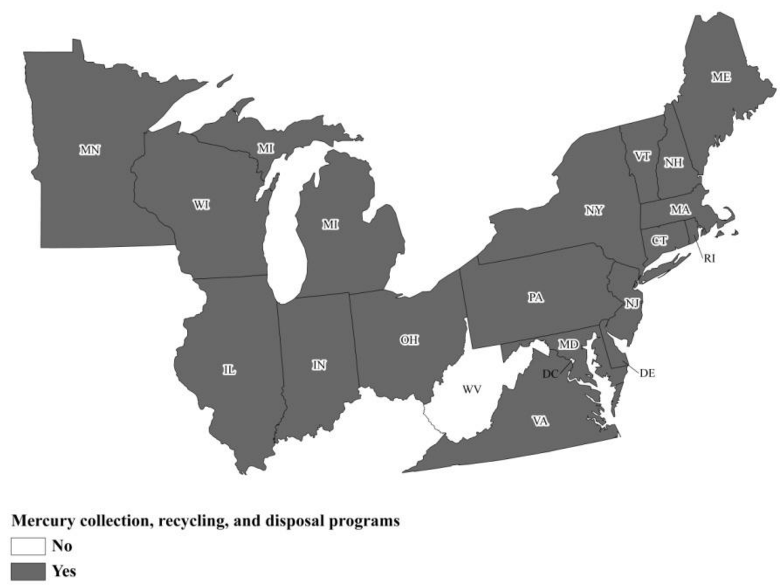

Figure 7. State Programs Regulating the Collection, Recycling, & Disposal of Mercury-Containing Products

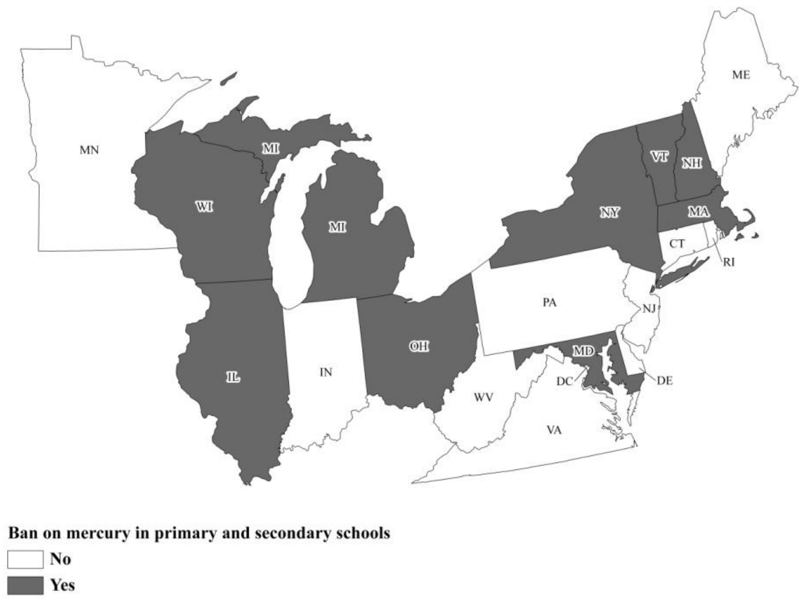

Figure 8. State Regulations Banning the Educational Use of Mercury in Primary & Secondary Schools

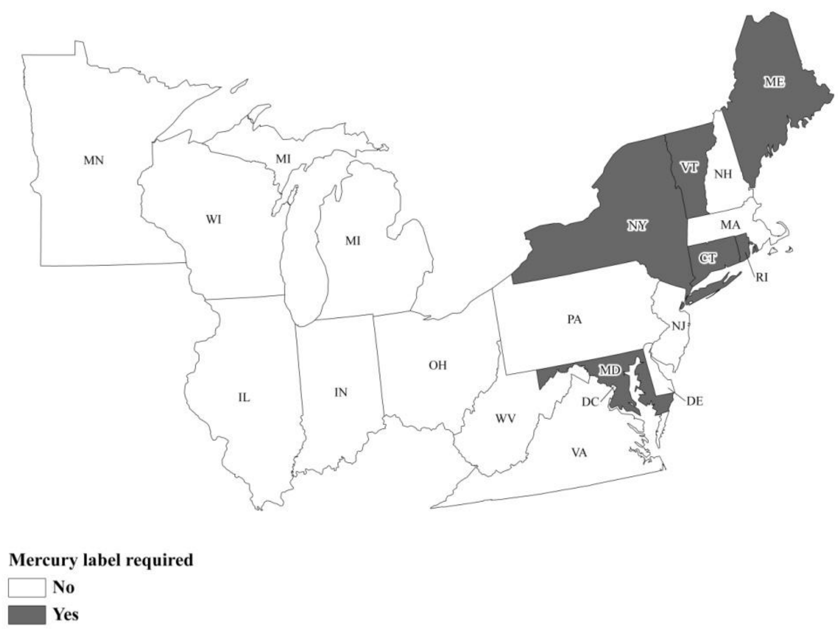

Figure 9. State Regulations Requiring Labeling of Mercury-Containing Products

Regulatory Landscape of Mercury in Northeastern Waters

Every state in the northeastern United States has reported mercury-impaired surface waters (Figures 10 through 17; Table 5). Mercury-impaired water bodies are those that did not meet SWQS for mercury concentration in either the water column, in fish tissue, or both, during monitoring. The extent of mercury contamination is expressed as the percent of assessed waters that were identified as impaired because of mercury concentrations in excess of state SWQS. This variable is divided into water body types, and each type of water body has a corresponding ratio of mercury pollution (Table 4).

The District of Columbia and Massachusetts water quality assessment reports released seemingly contradictory messages regarding mercury impaired water bodies. The District of Columbia reported no mercury impaired water bodies, but a statewide fish consumption advisory is in effect for all state waters because of mercury in fish tissue. Massachusetts reported no mercury-impaired water bodies, and a statewide fish consumption advisory is in effect for all fresh water and ocean waters. Massachusetts exemplifies the trouble with water quality reporting, that the actual impairment of state waters may be misrepresented as a result of flawed data collection and analysis. Massachusetts collaborated with six northeastern states and developed the Northeast Regional Mercury TMDL. Following US EPA approval of the Northeast Regional Mercury TMDL, the state removed all mercury polluted water bodies from the list of impaired waters. These waters are likely still contaminated with mercury, but the state is no longer required to report these water bodies as mercury impaired because a TMDL has been approved.

Other states structured their water quality assessment processes to classify as "impaired" any water body for which a fish-consumption advisory was issued. New Hampshire reported that all of the assessed state waters were mercury-impaired, and that a statewide fish-consumption advisory was in effect for all waters. Maine reported that all of the assessed fresh water bodies were mercury-impaired, and that a statewide fish consumption advisory was in effect for all of their fresh water bodies.

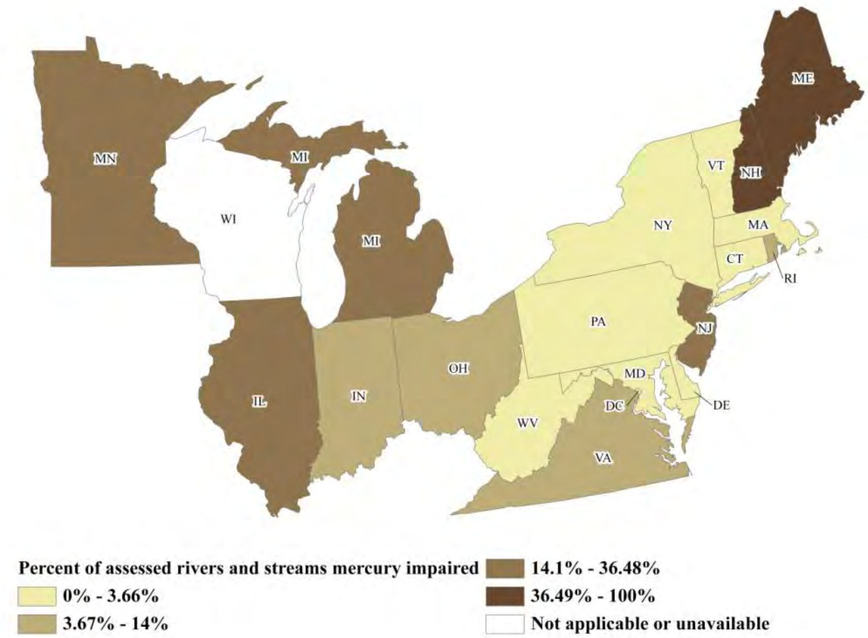

Figure 10. Extent of Self-Reported Mercury Contamination in Northeastern Rivers & Streams by State

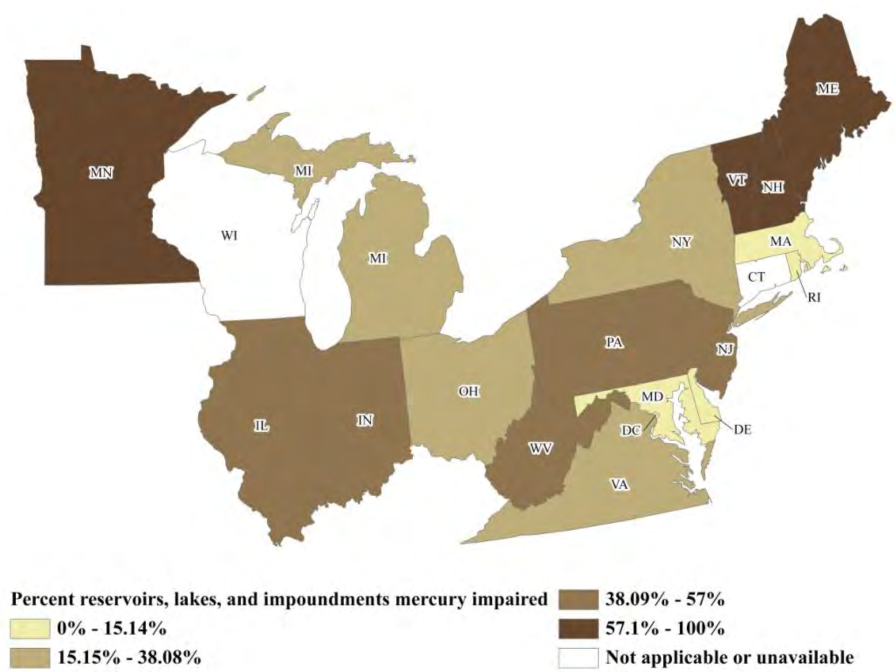

Figure 11. Extent of Self-Reported Mercury Contamination in Northeastern Lakes & Reservoirs by State

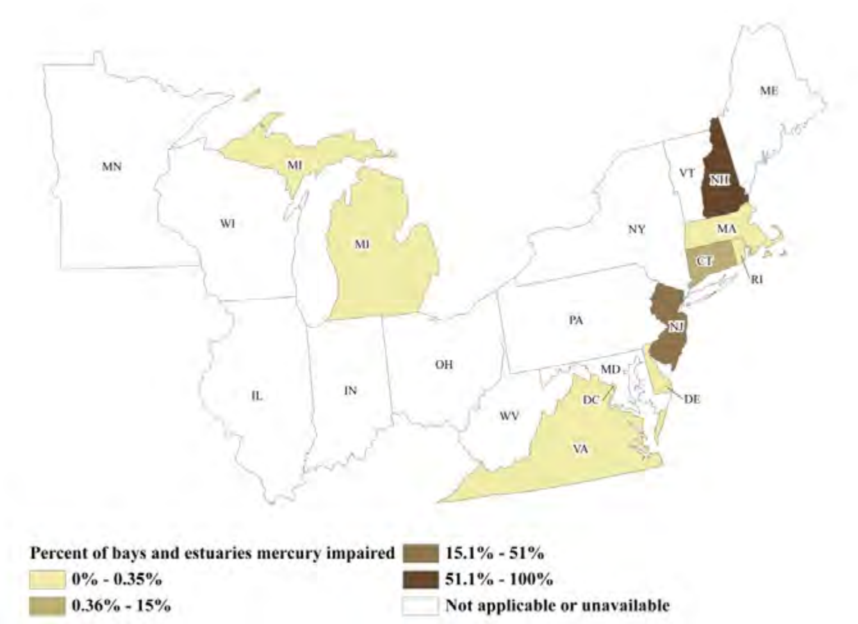

Figure 12. Extent of Self-Reported Mercury Contamination in Northeastern Bays & Estuaries by State

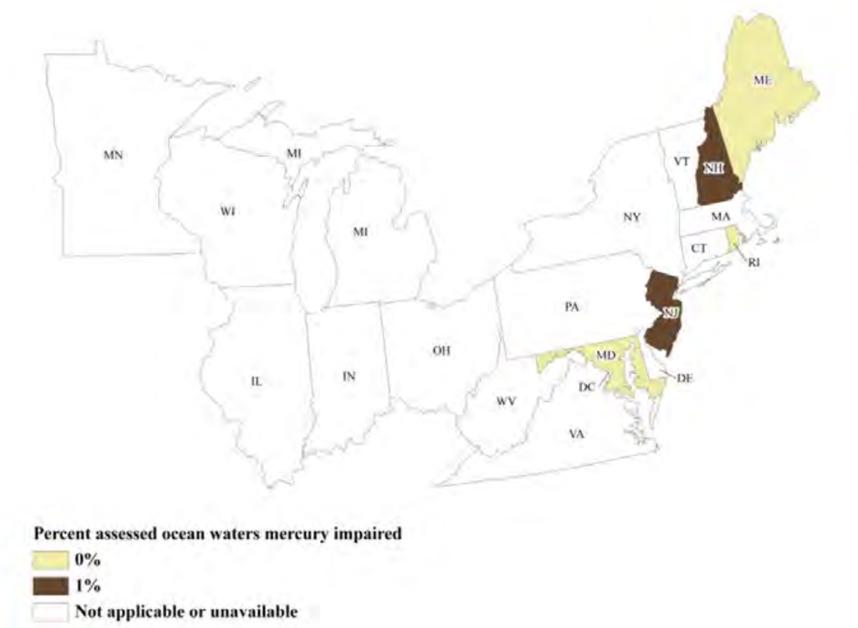

Figure 13. Extent of Self-Reported Mercury Contamination in Northeastern Ocean Waters by State

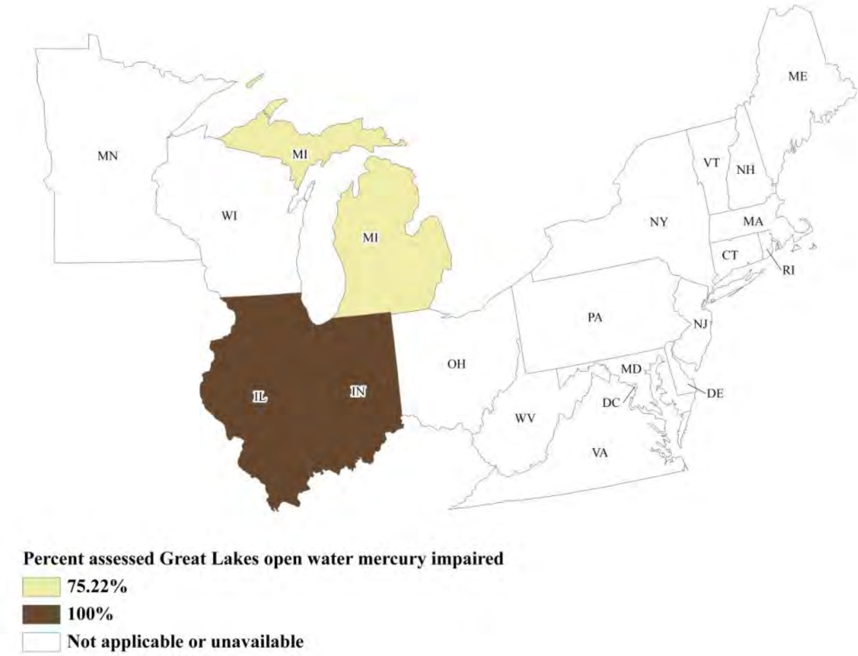

Figure 14. Extent of Self-Reported Mercury Contamination in Great Lakes Open Waters by State

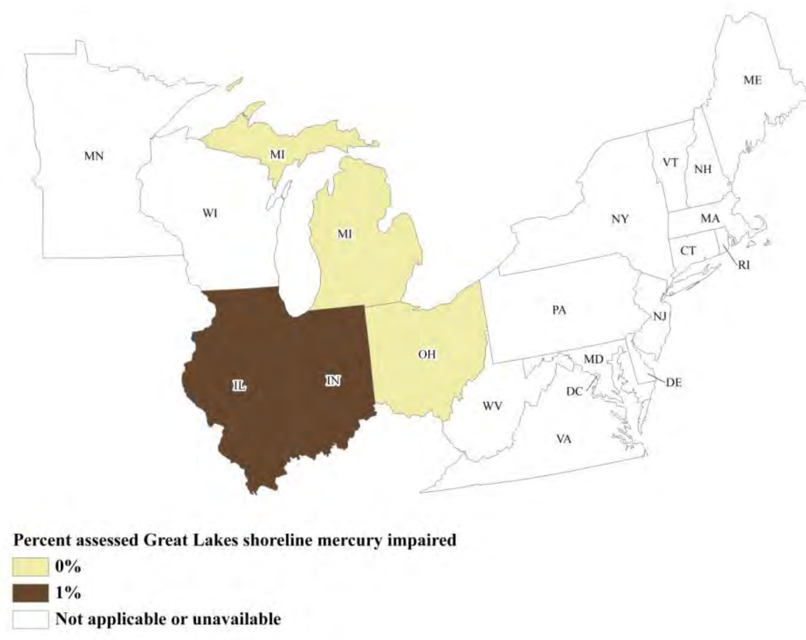

Figure 15. Extent of Self-Reported Mercury Contamination in Great Lakes Shoreline by State

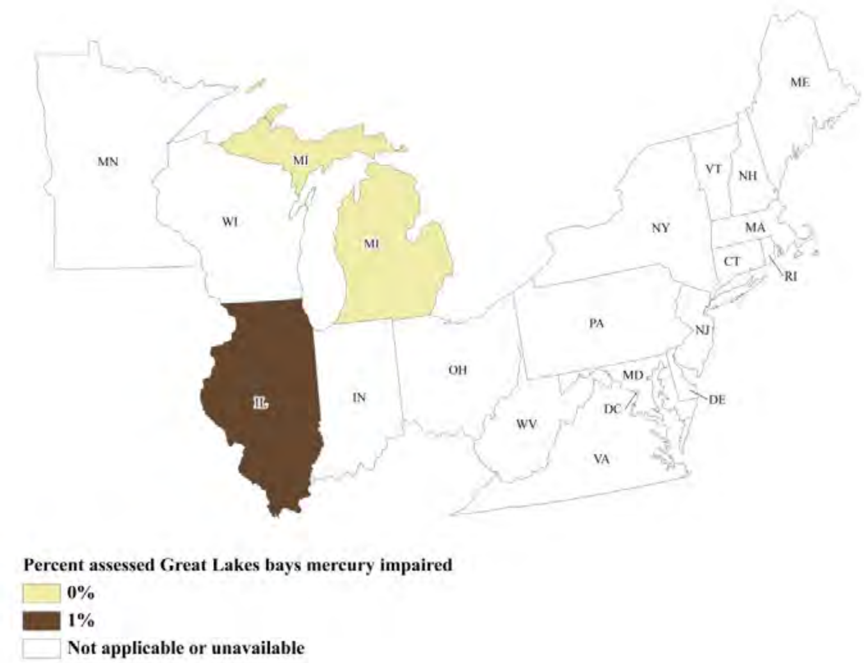

Figure 16. Extent of Self-Reported Mercury Contamination in Great Lakes Bays by State

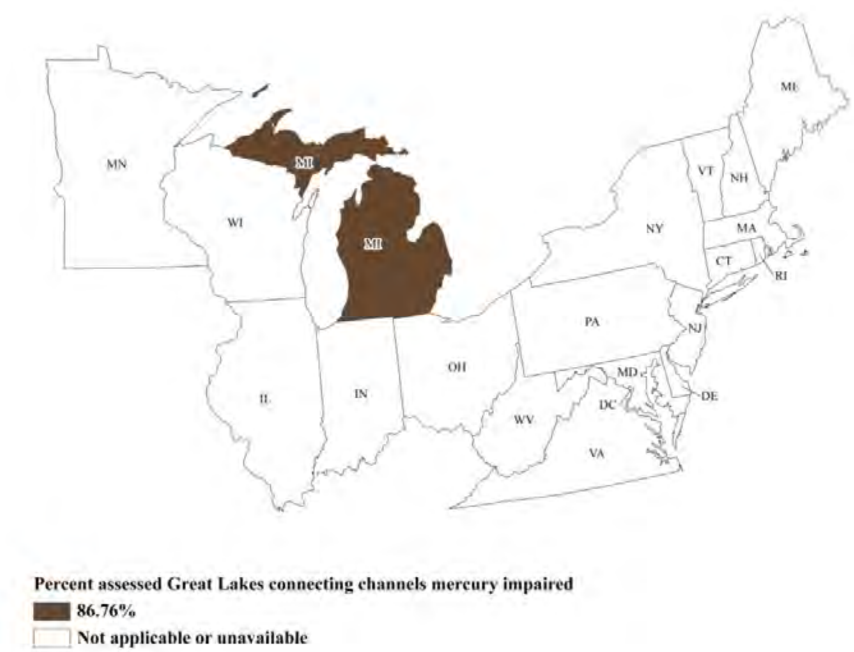

Figure 17. Extent of Self-Reported Mercury Contamination in Great Lakes Connecting Channels by State

Table 5. Extent of Self-Reported Mercury Contamination in Northeastern Surface Waters

State	Rivers & Streams	Lakes & Reservoirs	Bays & Estuaries	Ocean	Great Lakes Open Water	Great Lakes Shoreline	Great Lakes Bays	Great Lakes Connecting Channels	State-wide Fish Consumption Advisory for Mercury in Fish
CT	0.18%	3.01%	0.15%	NA	NA	NA	NA	NA	freshwater
DC	0	0	0	NA	NA	NA	NA	NA	all state waters
DE	0.96%	6.21%	0	UA	NA	NA	NA	NA	all state waters
IL	19.07%	48.79%	NA	NA	100%	100%	100%	NA	all state waters
IN	8.40%	54%	NA	NA	100%	100%	NA	NA	most inland waters
MA	0	0	0	NA	NA	NA	NA	NA	freshwater & ocean
MD	2.20%	15.14%	UA	0	NA	NA	NA	NA	lakes
ME	100%	100%	NA	0	NA	NA	NA	NA	freshwater
MI	26.92%	28%	0	NA	75.22%	0	0	86.76%	inland freshwaters
MN	36.48%	93.78%	NA	NA	NA	NA	NA	NA	freshwater
NH	100%	100%	100%	100%	NA	NA	NA	NA	all state waters
NJ	20%	57%	51%	100%	NA	NA	NA	NA	all state waters
NY	0.92%	38.08%	NA	NA	NA	NA	NA	NA	lakes
OH	5.99%	33.40%	NA	NA	NA	0	NA	NA	all state waters
PA	0.99%	44%	UA	NA	NA	UA	NA	NA	all state waters
RI	14%	0.60%	0	0	NA	NA	NA	NA	none
VA	8.47%	34.32%	0.35%	NA	NA	NA	NA	NA	none
VT	1%	79%	NA	NA	NA	NA	NA	NA	all state waters
WI	UA	UA	NA	NA	UA	UA	UA	NA	inland lakes
WV	3.66%	55.89%	NA	NA	NA	NA	NA	NA	all state waters

SWQS vary across the northeastern United States (Table 6). Every state must implement SWQS for mercury, as either mercury concentration in the water column (μg/L of mercury) or mercury in fish tissue (ppm of mercury) (US EPA 2009f). The US EPA issued guidance documents to assist states with the setting of their SWQS, but states are not required to adopt these standards (US EPA 2009f). In 2001, the US EPA published a guidance document recommending that states set SWQS for mercury in fish tissue at 0.3 ppm to protect human health (US EPA 2001). All states with fish tissue SWQS, except Michigan, have adopted a threshold at least as stringent as the US EPA recommendations. Michigan's standard is 0.35 ppm (Figure 18).

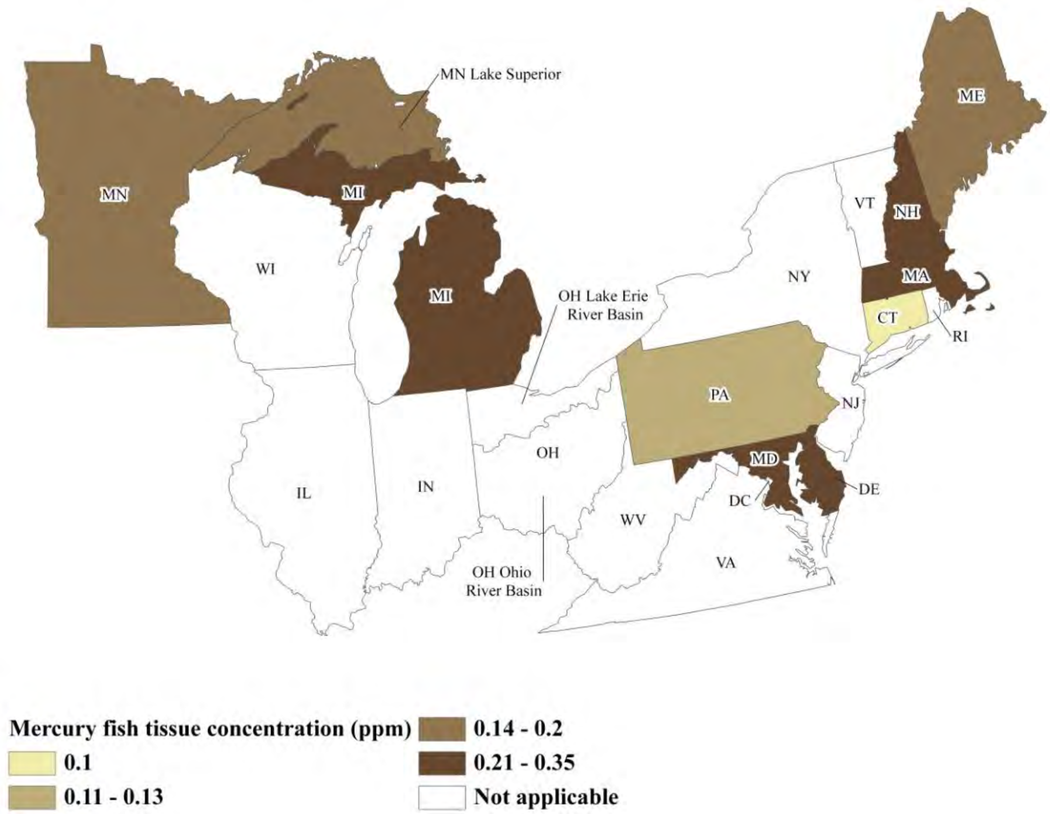

Figure 18. Surface Water Quality Standards, by State: Mercury Fish Tissue Concentration

All but three states have a SWQS for mercury in the water column (Figure 19). Maryland, Massachusetts, and Maine adopted SWQS for fish tissue concentrations rather than water column standards (Table 6; Figure 18). Six states have both water column and fish tissue concentration SWQS (Table 6). Although some states have not adopted a fish tissue criterion as part of their water quality standards, each state has a fish tissue concentration that they consider to be a part of the basis for issuing fish consumption advisories.

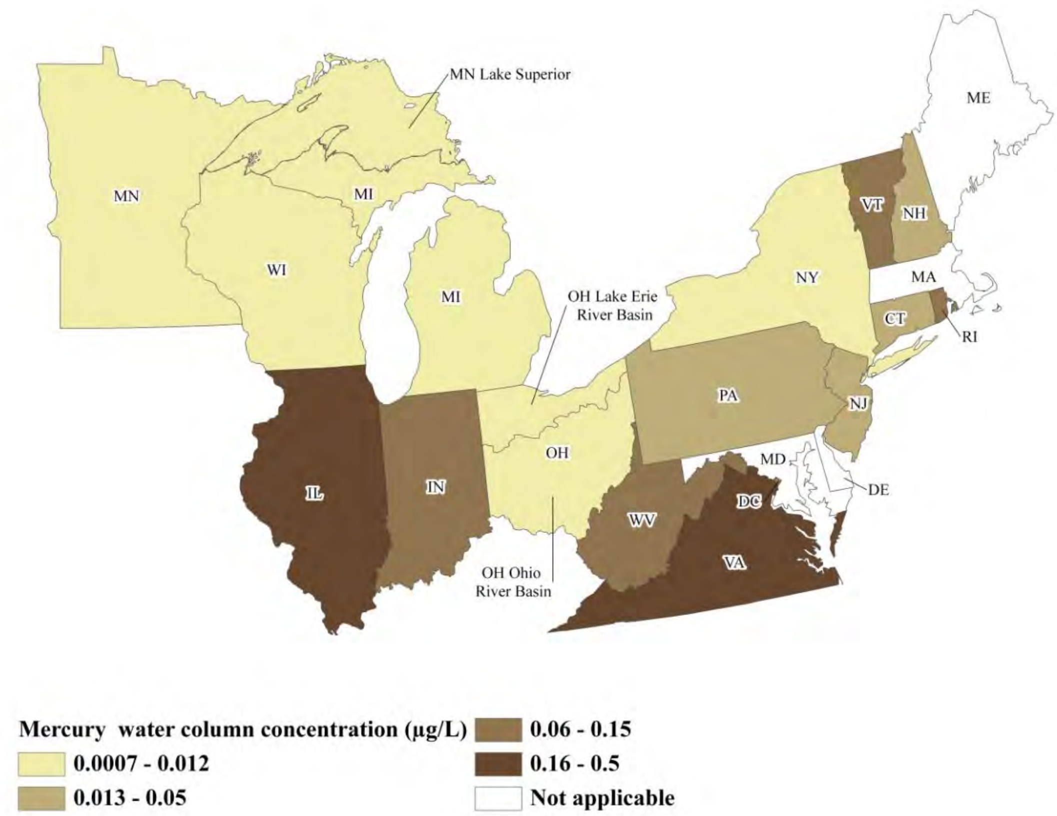

Figure 19. Surface Water Quality Standards, by State: Mercury Water Column Concentration

Minnesota and Ohio have two SWQS in place because the Great Lakes were deemed to require more stringent SWQS to protect aquatic life. Although Minnesota has two SWQS, one for all state waters and one for Lake Superior; the fish tissue concentration SWQS is the same for all waters. Ohio has set SWQS for mercury concentration in the water column of the Ohio River basein at 0.012 μg/L, and 0.0031 μg/L in the Lake Erie basin. New York has the most stringent SWQS at a concentration of 0.0007 μg/L of mercury in the water column. Illinois has the most lenient threshold for mercury in the water column at 0.5 μg/L (Table 6). SWQS measure both the stringency of state regulatory landscapes and a reflection of a state's acceptance of risk from mercury pollution.

Table 6. Surface Water Quality Standards in the Northeastern United States

STATE	Water Column Concentration (µg/L)	Fish Tissue Concentration (ppm)
CT	0.05	0.1
DC	0.15	NA
DE	NA	0.3
IL	0.5	NA
IN	0.14	NA
MA	NA	0.3
MD	NA	0.3
ME	NA	0.2
MI	0.0018	0.35
MN	0.0069	0.2
MN Lake Superior	0.0013	0.2
NH	0.05	0.3
NJ	0.05	NA
NY	0.0007	NA
OH-Ohio River Basin	0.012	NA
OH-Lake Erie River Basin	0.0031	NA
PA	0.05	0.13
RI	0.14	NA
VA	0.3	NA
VT	0.14	NA
WI	0.0015	NA
WV	0.14	NA

Mercury discharged from dental facilities is one of the largest sources of mercury discharged from POTWs into surface waters. No federal regulations exist to limit mercury discharges from this source category. Some states require dental facilities to install amalgam separators to remove mercury from wastewater before it is discharged to the POTW. The creation of state regulations setting dental facility discharge limits indicates the scope of state regulatory landscapes. The strength of this regulation (and the technology that is required to achieve it) is expressed as reduction efficiency; for example, a system capable of removing 99 percent of mercury has 99 percent reduction efficiency. Ten states in the northeastern United States have promulgated regulations requiring a minimum of 95 percent mercury removal efficiency (Figure 20). Indiana and Virginia have developed voluntary programs to encourage facilities to make reductions on their own (Table 7). Wisconsin places responsibility with the POTW, requiring all facilities exceeding 1.3 ng/L concentration of mercury in effluent to develop pollution-minimization plans (WI DNR 2010).

Figure 20. Regulations Requiring Mercury Reduction Efficiency from Dental Facilities

Table 7. State Regulations Requiring Mercury Reduction Efficiency from Dental Facilities

State	**State Regulations on Mercury Reduction Efficiency from Dental Facilities**
CT	minimum 95% reduction efficiency
DC	none
DE	none
IL	none
IN	voluntary reduction program, includes reduction strategies & educational materials for industry, and POTWs
MA	98% reduction efficiency
MD	none
ME	minimum reduction efficiency of 95% if installed prior to March 20, 2003 or 98% if installed on or after March 20, 2003
MI	By December 31, 2013 amalgam separator must be installed with minimum 95% reduction efficiency
MN	minimum 99% reduction efficiency
NH	minimum 95% reduction efficiency
NJ	minimum 99% reduction efficiency by Oct. 2009
NY	minimum reduction efficiency is 95% if installed prior to May 12, 2006; 99% if installed after this date
OH	none
PA	none
RI	99% reduction by July 2008
VA	voluntary reduction program, includes reduction strategies & educational materials for dental facilities
VT	require 95% dental amalgam reduction efficiency; By Jan 1, 2007,
WI	requires WWTPs that effluent exceeds 1.3ng/L mercury to develop pollution minimization program
WV	none

Regulatory Landscape of Mercury Air Emissions

Federal regulations have been established for mercury emissions from municipal and HMIW incinerators, and these are codified at 40 CFR Part 60, Subparts Cb, Eb, Ec, and Ce. US EPA issued final regulations on December 19, 1995 for mercury emissions from municipal waste combustors (US National Archives and Records Administration 1995 65387). New and existing sources must meet the mercury emissions limit of 0.08 mg/dscm, or 85 percent control (US National Archives and Records Administration 1995 65387). US EPA finalized emission standards on September 15, 1997 for HMIW incinerators (US National Archives and Records Administration 1997 48348). Mercury limits for new and existing sources are 0.55 mg/dscm, or 85 percent control, and facilities are required to develop mercury waste management plans (US National Archives and Records Administration 1997 48348).

All states must comply with federal standards for mercury emissions from municipal waste and HMIW incinerators. Connecticut and New Jersey passed regulations that are more stringent for municipal waste incinerators, and New Hampshire and New York developed more stringent regulations for HMIW incinerators (Table 8; Figure 21; Figure 22).

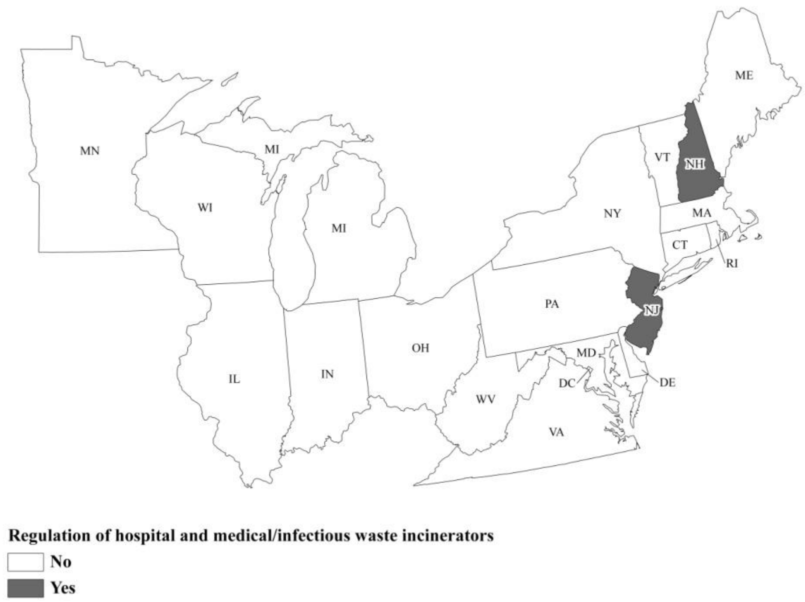

Figure 21. Regional Regulations Exceeding US EPA Emission Standards for HMIW Incinerators

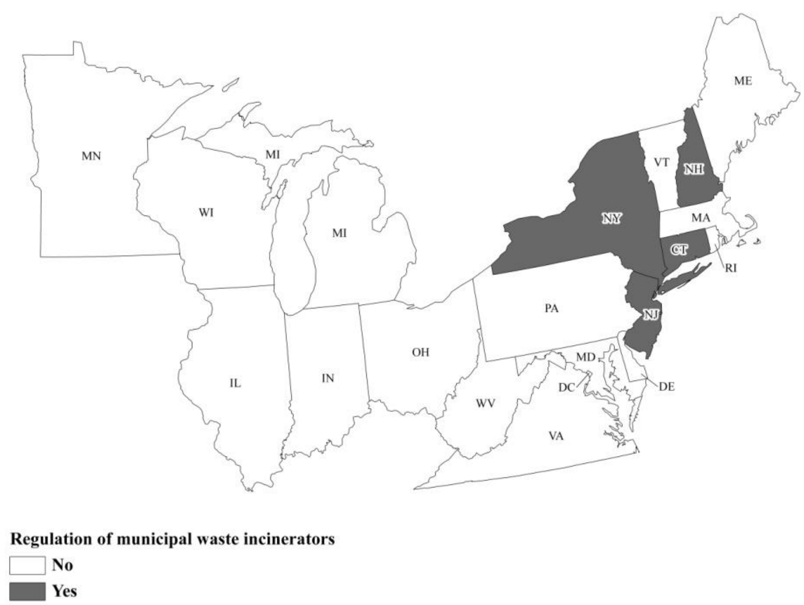

Figure 22. Regional Regulations Exceeding US EPA Emission Standards for Municipal Waste Incinerators

Table 8. State Regulations on Mercury Air Emissions

State	Coal Power Plants	Municipal Waste Incinerators	HMIW Incinerators
EPA	none	0.08 (80 ug) mg/dscm or 85% reduction from, whichever is less stringent	0.55 (550 ug) mg/dscm or 85% reduction
CT	90% mercury emissions reduction	maximum 28 ug/dscm	same as EPA
DC	none	same as EPA	same as EPA
DE	By Jan 2009 80% reduction in mercury emissions; By Jan 2013 90% reduction	same as EPA	same as EPA
IL	90% mercury emissions reduction	same as EPA	same as EPA
IN	none	same as EPA	same as EPA
MA	By 2008: 85% reduction in mercury emissions, or emit max 0.0075 lbs/GWh. By 2012, 95% reduction in mercury emissions, or emit max 0.0025 lbs/GWh	same as EPA	same as EPA
MD	By 2010 80% reduction in mercury emissions; By 2013 90%	same as EPA	same as EPA
ME	Annual mercury emissions cap: 35 lbs/yr in 2007 & 25 lbs/yr in 2010. Mercury reduction plan required for facilities emitting more than 10 lbs/yr	same as EPA	same as EPA
MI	90% mercury emissions reduction by 2015	same as EPA	same as EPA
MN	none	same as EPA	same as EPA
NH	80% reduction in mercury emissions by 2013 & economic incentives for earlier installation & greater reductions	95% reduction in mercury emissions	99% reduction
NJ	90% reduction in mercury emissions by 2007	85% reduction by 2006, 95% by 2012; maximum 28 ug/dscm	55.0 µg/dscm
NY	By 2010 50% reduction in annual emissions; By 2015 90% reduction	28 µg/dscm or 85% reduction	same as EPA
OH	none	same as EPA	same as EPA
PA	90% reduction in mercury emissions by 2015. In 2009 PA court declared rule invalid & unenforceable	same as EPA	same as EPA
RI	no coal power plants	same as EPA	same as EPA
VA	Established a phased reduction of mercury emissions. When CAMR was vacated, VA stopped enforcing. New sources regulated on case-by-case basis,working MACT requirements into air permits	same as EPA	same as EPA
VT	no coal power plants	same as EPA	same as EPA
WI	70% by 2015; 80% by 2018; 90% reduction in mercury emissions by 2021	same as EPA	same as EPA
WV	none	same as EPA	same as EPA

Currently there is no federal regulation of mercury emissions from coal power plants. The attempts to regulate mercury from coal power plants have a long and contentious history, and have created a highly fragmented regulatory landscape for this source. To understand the complexity of the regulatory landscape for this emission source, one must appreciate the long road to mercury regulation.

The 1990 Amendments to the CAA incorporated section 112 which identified mercury as a hazardous air pollutant (HAP), and required the US EPA to set emission standards for sources of mercury (US EPA 2010e). In addition, section 112(n)(1)(A) of the CAA directed the US EPA to study the health hazards of HAP emissions from electric-utilities, including coal-fired power plants, and to regulate sources if "such regulation is appropriate and necessary" (US EPA 2010e). US EPA issued the results of this research in December of 2000, and determined that it was appropriate and necessary to regulate mercury emissions from coal-fired power plants. Following these findings, the US EPA began the process of gathering data to develop emission standards. Section 112 requires the US EPA to develop emission standards based on the best performing 12 percent of existing sources, referred to as maximum achievable control technologies (MACT) (Milford and Pienciak 2009).

In 2004, the US EPA issued a notice of proposed rulemaking that outlined two alternatives: revising the findings of December 2000 to remove power plants from section 112 and regulate this source category under "new source performance standard" of section 111, or to regulate power plants under section 112 through a cap-and-trade approach rather than following MACT requirements under this section of the CAA. In March 2005, US EPA announced the Clean Air Mercury Rule (CAMR), which removed power plants from section 112, and regulated mercury emissions from coal-fired power plants with a cap-and-trade program under section 111.

The cap-and-trade approach fell far short of reducing coal-fired power plant mercury emissions. Once the rule was finalized, seventeen state agencies, the City of Baltimore, the National Congress of American Indians and Treaty Tribes, and several environmental and public health organizations appealed the law. In February 2008, the D.C. Circuit Court vacated the CAMR citing the US EPA action of "delisting" power plants from section 112 was illegal. The court also directed the US EPA to promulgate federal regulations for mercury emissions from power plants under section 112 of the CAA, these regulations are expected in early 2011.

Vacation of the CAMR represents further fragmentation and confusion within the regulatory landscape of mercury air emissions. Many state regulations implemented under the legal authority of the CAMR are no longer enforceable. Some states are hesitant to promulgate regulations, and await action by the US EPA. The regulatory landscape is further complicated by CAA amendments introduced in February 2010. These amendments aim to cut mercury emissions by at least 90 percent by 2015. These proposed amendments attempt to ensure mercury emissions will be limited in a timely manner, rather than waiting for US EPA rules to be finalized and implemented (WI DNR 2010).

Thirteen states in the northeastern United States have developed regulations limiting mercury emissions from coal-fired power plants (Figure 23; Table 8). Rhode Island and Vermont have no coal-fired power plants within their borders. The regulations in these thirteen states may or may not be enforceable depending on the wording of the regulations, whether CAMR was referenced, and the ways in which the regulations were incorporated into the state implementation plan. The enforcement status of these regulations is not within the scope of this research; however, these data were included to characterize the regulatory intent of each state, and to measure the stringency of intended regulation for mercury emissions from coal-fired power plants. Regulation of coal-fired power plants reflects the scope of state regulatory landscapes, and the mercury emission reductions required measure the stringency.

Two clusters within the study area regulate mercury emissions from coal-fired power plants; one is located to the northeast and the other around the Great Lakes. These geographic clusters probably have wider scopes of regulation because of the issue-salience within these two regions. Strong regional collaboration and a collective goal to reduce mercury emissions encourage regulations in the northeastern portion of the study area. Motivation to protect the Great Lakes might explain this regulatory cluster around the Great Lakes. Within both clusters, states without regulations are present, demonstrating the lack of consensus regarding the regulation of this source of mercury emissions.

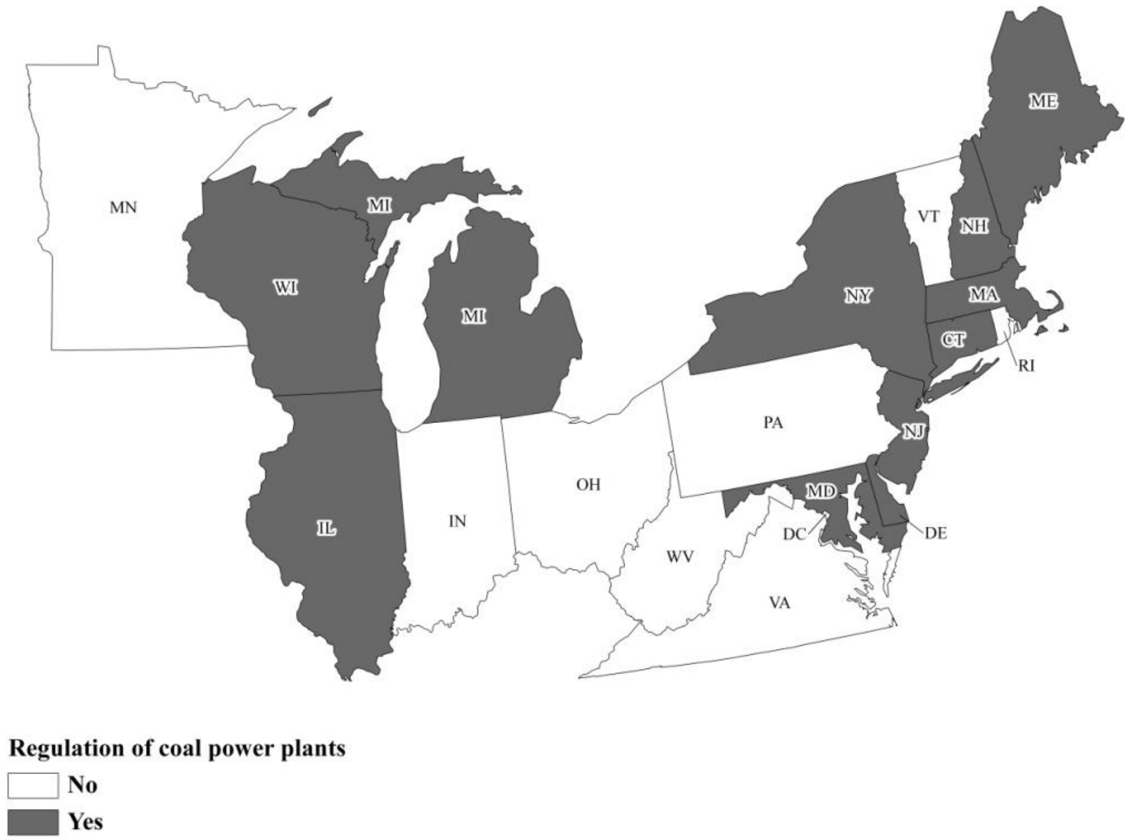

Figure 23. Regional Regulations for Mercury Emissions from Coal Power Plants

Regional Mercury Management Organizations

Regional organizations that address mercury in the environment play an important role in assisting states with the creation and implementation of comprehensive management strategies. In addition, state collaboration through regional organizations is crucial to the development of a smooth regulatory landscape, and could more effectively limit mercury in the environment. Several regional organizations support the regulation and management of mercury across the northeastern United States. In total, fourteen of the twenty states studied here are members of at least one regional organization, the remaining six states do not subscribe to regional organizations that address mercury in the environment (Figure 24; Table 9).

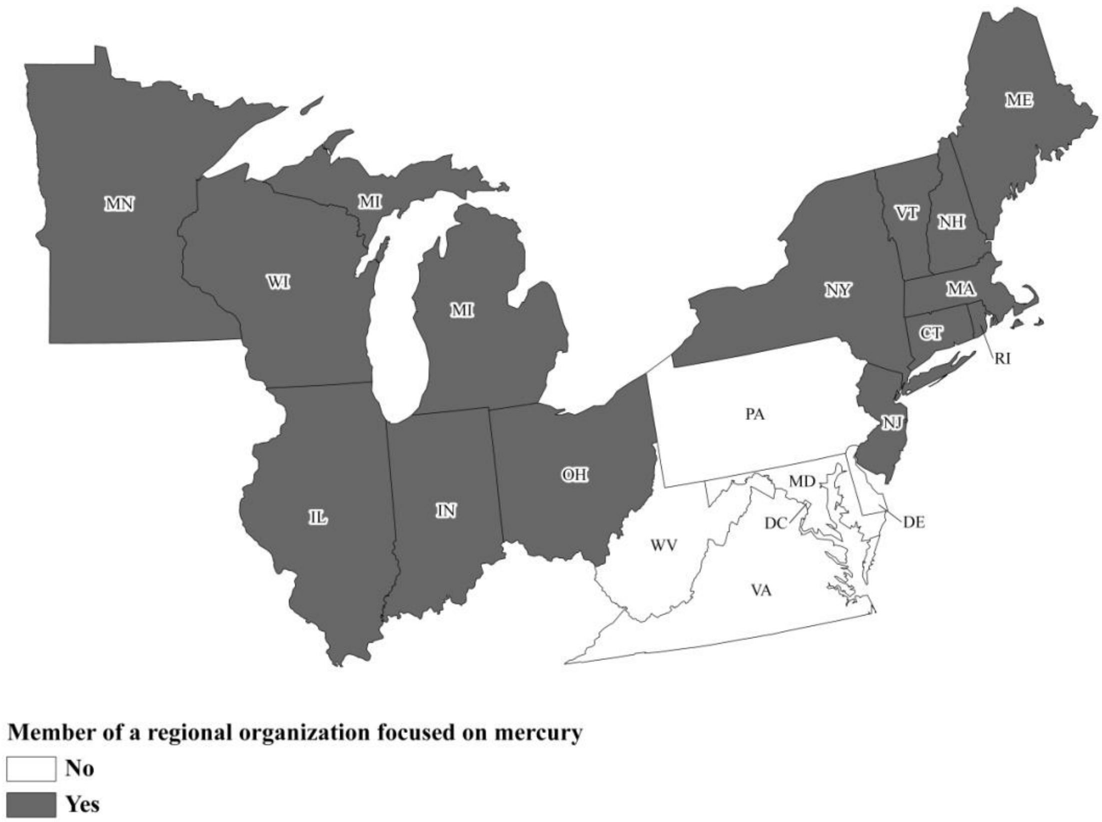

Figure 24. Membership in Regional Organizations Addressing Mercury in the Environment

Table 9. State Membership in Regional Organization Addressing Mercury in the Environment

State	Regional Organizations
CT	NESCAUM; IMERC; NEG & ECP; NEWMOA; NEIWPCC
DC	none
DE	none
IL	IMERC; Binational Toxics Strategy Mercury Workgroup
IN	Binational Toxics Strategy Mercury Workgroup
MA	NESCAUM; IMERC; NEG & ECP
MD	none
ME	NESCAUM; IMERC; NEG & ECP
MI	Binational Toxics Strategy Mercury Workgroup
MN	IMERC; Binational Toxics Strategy Mercury Workgroup
NH	NESCAUM; NEG & ECP; NEIWPCC; IMERC
NJ	NESCAUM; IMERC
NY	NESCAUM; IMERC; Binational Toxics Strategy Mercury Workgroup
OH	Binational Toxics Strategy Mercury Workgroup
PA	none
RI	NESCAUM; IMERC; NEG & ECP; NEWMOA
VA	none
VT	NESCAUM; IMERC; NEG & ECP
WI	Binational Toxics Strategy Mercury Workgroup
WV	none

Northeast States for Coordinated Air Use Management (NESCAUM) is a non-profit organization of air quality agencies in the northeastern United States. NESCAUM's members are Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, and Vermont. The organization was founded in 1967 to provide scientific, technical, analytical, and policy support to air quality programs within the member states (NESCAUM 2010). NESCAUM assists with the quantification of environmental mercury, and the development of management programs (NESCAUM 2010).

New England Interstate Water Pollution Control Commission (NEIWPCC), founded in 1947, is a non-profit interstate agency that serves eight members: Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, and Vermont. Thirty-five commissioners, five from each state, oversee the organization's operations. The commissioners are a diverse group and with a range of backgrounds, coming from industry, health departments, environmental agencies, the public, and municipalities (NEIWPCC 2009a). NEIWPCC serves the members states by coordinating activities and forums to encourage cooperation, provide public education forums, research, and training for environmental professionals (NEIWPCC 2009a). NEIWPCC has developed a successful strategy of coordinating workgroups composed of state and federal agencies that collaborate on specific water pollution projects (NEIWPCC 2009a).

Beginning in 2005, the NEIWPCC coordinated with member states, excluding New Jersey, to create a regional TMDL to address mercury-contaminated waters in the region (NEIWPCC 2007). The US EPA approved the Northeast Regional Mercury TMDL in December 2007. The Northeast Regional Mercury TMDL set a goal to reduce atmospheric deposition of mercury by 98 percent from both in-region and out-of-region sources (NEIWPCC 2007). Even with significant in-region reductions in mercury emissions, the reduction rate required in the Northeast Regional Mercury TMDL is not possible without reductions in surrounding states (NEIWPCC 2007). In an attempt to ensure the attainment of out-of-region reductions, NEIWPCC, and member states (excluding New Jersey) employed section 319(g), a provision of the Clean Water Act that has never been used before (NEIWPCC 2009b). This section allows for the petition of the US EPA to convene a management conference that includes all states considered significant sources of mercury in northeastern waters (NEIWPCC 2009b; US EPA 2010g). The conference is to be held to develop an agreement among relevant states to reduce mercury pollution and improve water quality in the region (US EPA 2010g). This unprecedented multi-state action exemplifies the determination of NEIWPCC member states to achieve mercury reductions in order to protect wildlife and human health (NEIWPCC 2009b). This is a unique strategy compelling the US EPA to address atmospheric deposition of mercury, particularly focusing upon water bodies, in the region (NEIWPCC 2009b).

Northeast Waste Management Officials' Association (NEWMOA) is a non-profit interstate organization created by the governors of the New England states. NEWMOA, officially recognized by the US EPA in 1986, coordinates interstate waste (hazardous and solid waste), pollution prevention, and clean-up efforts. NEWMOA's mission is to develop effective partnerships among member states to achieve a healthy environment by implementing sustainable solutions. To this end, the Interstate Mercury Education and Reduction Clearinghouse (IMERC) is an online database to provide a single source of information regarding mercury-added products, and mercury waste reduction. IMERC was created to assist in the decision-making process as states develop mercury management programs (NEWMOA 2010a).

The New England Governors' Conference (NEGC) began as an informal alliance during colonial times, and became a formal interstate organization in 1937 (NEGC 2010). NEGC became a non-profit organization in 1981, and convenes annually to coordinate policies and management programs to address regional issues (NEGC 2010). The six members are: Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont. The NEGC also coordinates with the annual Conference of New England Governors' and Eastern Canadian Premiers (NEG & ECP) (NEGC 2010). The NEG & ECP is a bi-national coordination of governments committed to addressing environmental issues that span the United States-Canada boundary along the eastern seaboard (NEGC 2010).

The Great Lakes Bi-national Toxics Strategy (GLBTS) is a collaborative effort between Canada and the United States aimed at the virtual elimination of PBT pollutants, including mercury, in the Great Lakes (US EPA 2010h). Members of GLBTS include Illinois, Indiana, Minnesota, Michigan, New York, Ohio, and Wisconsin. GLBTS, formed in 1997, contributes to a smooth regulatory landscape by creating a consistent framework for actions aimed at reducing and eliminating mercury from the Great Lakes basin. To eliminate mercury from the Great Lakes basin, GLBTS formed a Mercury Workgroup to coordinate reduction strategies and ensure reduction targets were met (US EPA 2010h). The Mercury Workgroup has complied research on sources of mercury, regulations addressing mercury, and reduction options available. In addition, the broad goals of GLBTS have encouraged member states to implement regulations reducing mercury in the environment.

States that collaborate with one or more regional organization addressing mercury in the environment are more likely to develop comprehensive mercury regulations. Regional organizations offer states support in the form of shared resources to apply towards mercury research and regulatory insight from other member states grappling with similar environmental management challenges. Additionally, as mercury pollution does not respect political boundaries, collaboration offers increased regional efficacy in mercury regulation and reduction in the environment. This geographic pattern is an example of the idea of strength in numbers: states with membership in regional collaborations are therefore more likely to develop effective and economically feasible management strategies.

State Research

Seventeen states within the northeastern United States have conducted research on mercury in the environment (Table 10). Three states have conducted no research regarding environmental mercury. The research conducted varies in topic and scope, but most aims to support some aspect of the regulatory landscape and/or assist in management efforts. These data characterize the resources that states have committed to mercury management, as well as the priority of mercury hazards within the state regulatory framework. A lack of research by a state does not imply that it is taking no action. Often, states share and make not of each other's research results, modeling techniques, and document structure for TMDLs. For example, the Northeast Mercury

TMDL was modeled after the Minnesota statewide mercury TMDL document. Through this process of sharing, valuable “collective knowledge” is created.

Table 10. State Research Addressing Mercury in the Environment

State	State Research on Mercury in the Environment
CT	2001 Annual Environmental Compliance Report: a progress report on management & reduction of mercury in the environment ; 2000 Toward Virtual Elimination of Mercury from Solid Waste Stream: collecting mercury in schools & households & limiting mercury in the environment
DC	None
DE	None
IL	2005 Reducing & Recycling Hg Switch Thermostats & Vehicle Components
IN	2007 Report on Terms & Concepts to Understand Mercury Reduction Policy
MA	A long-term monitoring network of lakes was established in 2001 to provide temporal tracking of changes in the mercury contamination status of fish in the Commonwealth, particularly as comprehensive mercury use & emissions reductions efforts have been implemented in Massachusetts and regionally. Massachusetts Mercury Task Force developed a Zero Mercury Strategy with the goal of virtual elimination of both the use & release of anthropogenic mercury
MD	2002 & 2004 Report on Mercury & Mercury Added Products: effectiveness of the state law & progress on reducing mercury in the environment
ME	2002 Mercury in Maine: a status report on the success of current reduction strategies and needs for additional programs
MI	2008 Mercury Strategy Staff Report; Michigan's Mercury Electric Utility Workgroup final report 2005
MN	Sources of mercury pollution, reduction strategies, economic benefits of reducing mercury; mercury reduction progress reports to MN Legislature
NH	Analysis for the Fish Mercury Trend Monitoring Program-scientific design to detect small changes over time
NJ	NJ Mercury Reduction Action Plan Draft 2009; Cultural Uses of Mercury 2007; Removal of Mercury Switches from Surplus NJ Vehicles 2006; Statistical & Analytical Assessmt of EPA's proposed MACT Standards for Coal power plants 2004; Assessment of mercury in fish from NJ surface waters 2002
NY	Mercury Work Group Recommendations; Linking science with public policy; Mercury in products phase down strategy
OH	Mercury in products phase-down strategy report; Mercury reduction guidance for POTWs
PA	State plan for mercury emissions control coal; 2009 Evaluation of PA air quality program
RI	none
VA	Mercury Study: emissions data analysis & deposition modeling, assess human health risks; South River Science Team: funded by DuPont, 100 yr monitoring study, biannual reports on Mercury Monitoring; State Advisory Board Mercury Research: emissions control technologies
VT	Variety of research on biochemistry of mercury, health effects, atmospheric deposition & bioaccumulation; 2010 VT Advisory Committee Annual Report on Mercury Pollution; 2004 Report on Biogeochemistry of Mercury in VT & NH Lakes
WI	Mercury Monitoring & Modeling Research; 2004 Report on development of atmospheric mercury monitoring program for the Great Lakes region
WV	Survey of WV Residents' Consumption of Fish

Geographic Patterns

This study reveals that the northeastern United States has a dynamic and complex regulatory landscape of mercury management with distinct geographic patterns. In the end, the District of Columbia, Delaware, and West Virginia have the least comprehensive regulatory landscapes. These places lack clear approaches to reducing mercury in their environments, and demonstrate little initiative to construct more consistent regulatory landscapes at the state-level. In contrast, comprehensive regulatory landscapes for mercury management are found in Connecticut, New Jersey, New York, and Vermont.

Overall, New England tends to have a more comprehensive regulatory scope characterized by more stringent regulations and greater collaboration. This geographic pattern may be explained by the longer-term experience with industrial pollution in this region. The Great Lakes region has similar geographic patterns, however collaboration, scope and stringency are not as well developed as in the New England region. This is somewhat surprising given that the Great Lakes contain the largest pool of freshwater in the region and mercury contamination in this region justifies significant issue-salience.

Great Lakes states tend to be more involved in regional organizations addressing mercury in the environment; however, proximity to the Great Lakes does not appear to require that their regulations are more stringent. New England also has high regional organization participation in addressing mercury in the environment, but the south central states in the study have very little regional organization activity. New England has a long history of collaboration, and this contributes to the success of current collaborative environmental management initiatives. The south central region of the study area, characterized by several highly industrial landscapes, has a history of policies that encourage economic growth and weaken environmental regulations. States with higher levels of collaboration do not necessarily have a wider scope of regulation; however, states that do not collaborate tend to have a narrow regulatory scope.

Regulations on mercury discharges from dental facilities are found exclusively in New England and Michigan. SWQS for mercury in the water column are more stringent in the northern part of the study area and less stringent in the southern portion of the study area. Great Lakes states also tend to have standards that are more stringent. SWQS for mercury in fish tissue do not conform to a geographic pattern. Connecticut has the most stringent standard (0.1 ppm), followed closely by Pennsylvania (0.13 ppm), and Michigan has the least stringent standard (0.35 ppm). Michigan's SWQS is above the US EPA recommended level of 0.3 ppm.

Regulations on mercury emissions from waste incinerators that are more stringent than US EPA regulations are clustered in New England. New Hampshire and New Jersey have more stringent regulations than the US EPA for MHIW incinerators, all other states comply with US EPA regulations. Regulations addressing mercury emissions from coal-fired power plants are present in all New England states, except Vermont. In addition, some Great Lakes states have regulations in place. In general, those states with high stringency also have a large scope of mercury regulations, but some exceptions exist.

Issue-salience is the most difficult attribute to measure among state regulatory landscapes. The variables that measure issue-salience include the extent of mercury contamination and state research on mercury in the environment. The difficulty of measuring issue-salience lies in the data collection and reporting framework. It is difficult to compare mercury contamination data between states because different types of water bodies may present different public health risks. For example, in some northeastern states more recreation may occur in coastal waters than in freshwater settings. Clarification may be achieved by collecting data on recreation patterns within each state; however, recreation behavior is beyond the scope of this study. In addition, states assess water quality using different methods, and categorize waters as impaired differently, these and other issues make data comparisons difficult.

State discretion with water quality reporting must be considered when evaluating the veracity of water quality data. States have a considerable amount of freedom in determining how to categorize surface waters' levels of impairment, and states' choices during this process affects the quality and effectiveness of public health messages. A consistent regulatory landscape would enable clearer public health communication regarding mercury contamination of fish. The federal government could help to achieve this goal by releasing more guidance documents to states. Moving from guidance to full-blown regulation would establish a consistent and level regulatory landscape.

Overall, a lack of clear federal rules and guidance regarding environmental mercury is evident across the northeastern U.S. The top priority within the region is a focus on SWQS and fish consumption advisories or bans. This is a reactive approach prevalent throughout the region. However, some states are becoming proactive and removing mercury from as many products and processes as possible in order to remove mercury from the environment before it becomes a public health hazard. The nature of mercury in the environment is such that, a proactive approach will yield greater results than reactive approaches. Once mercury enters an ecosystem, it will persist for decades to come.

CHAPTER VI

DISCUSSION

The regulatory landscape of mercury management has developed over the last twenty years and is becoming a priority among many states in the region. This is due to a recent focus on the pollutant, its sources, as well as its toxicity to humans and in the environment. Clear and explicit federal regulations would provide consistency in mercury regulations across the region. However, the lack of a consistent federal regulatory landscape for mercury management has not stopped a handful of states from regulating mercury in the environment. As a result, a patchwork of regulations exists among and across states, resulting in a fragmented regulatory landscape for mercury management.

This research demonstrates the need for clear, and comprehensive federal regulations that create minimum standards for mercury management in the waste stream, air emissions and water discharges. The success of the CWA's technology-based approach has proven federal standards ensure progress is made toward the long-term goal of improving water quality.

A comprehensive federal approach to mercury management would benefit state-level mercury reductions, public health, and the health of United States surface waters. Experience with a similar environmental toxin, lead, indicates a federal approach to reducing lead in the environment was integral to achieving the necessary reductions of ambient lead in the environment to protect human health. Following a long struggle, lasting more than three decades, federal regulations imposed a minimum standard for lead removal by eliminating lead from most processes and products. The process of regulating lead required a re-assessment of scientific and public perceptions regarding lead toxicity, as well as a commitment to protect human health in the face of objections from industry that regulations were too costly (Needleman 2000). The nature of lead pollution is elusive, similar to mercury pollution, because it transfers easily among air and water, necessitating regulation at the source.

One important similarity between mercury and lead regulation is the contentious debate regarding accurate estimates of the dose-response relationships for toxicity of these two pollutants. The US EPA formulates regulations based on scientific studies that show a clear relationship between exposure to a pollutant, and the resulting health effects. Carefully proceeding from scientific studies to establishing regulations is a valuable exercise in environmental regulation. However, the lead experience demonstrates that the scientific "consensus" necessary for effective regulation may be used as a delay tactic by industry.

The dominant debate slowing progress of mercury management is disagreement among stakeholders regarding transport and deposition of mercury emissions, and the human health and environmental hazards presented by mercury pollution. While there is a consensus that mercury pollution is cause for concern, the level of concern and the priority of mercury pollution varies across the region. The passage of federal regulations would put some of this debate to rest, and would set the minimum standard for an acceptable level of risk. More research is necessary to better understand mercury in the environment; however, uncertainty will always exist, and real costs to human health and environmental quality are associated with inaction.

Across the region, mercury pollution is addressed through the TMDL process. The TMDL process is a water quality-based approach defined in the CWA to address waters impaired by NPS pollution. TMDLs rely on voluntary reductions from mercury sources within a watershed to achieve reductions necessary to protect human and aquatic life. This process is time consuming and contentious, additionally, the effectiveness of TMDLs for addressing mercury pollution is debatable. Mercury in the environment is largely the result of point source pollution; however, mercury is managed as a NPS pollutant.

Mercury from coal-fired power plants, waste incineration, dental facilities, and mercury-containing products can and should be regulated as point source pollutants. Similar point source pollutants regulated as NPS pollutants include: nitrogen and phosphorus, persistent pesticides, and heavy metals. Rather than regulating these pollutants at the source, the US EPA has developed a quiet policy of addressing these toxins once they are identified as impairments in water bodies. By adopting proactive approaches to eliminating toxics prior to entering the environment, the US EPA would save taxpayer money, protect human health and aquatic life, and be one step closer to achieving the fishable and swimmable goal of the CWA. The CWA requires point source pollution to be regulated through the technology-based approach of the CWA, which is achieved by removing pollutants from emissions, water discharges, and the waste stream. However, it is common practice for the US EPA to delay regulations on point source emissions for decades in an effort to obtain more science to inform regulations.

Collaboration among states in a region is a key element to the successful management of mercury in the environment. States that are involved in regional organizations are more likely to develop comprehensive mercury regulations. In addition, a collaborative approach to regulation and policy formulation and can save valuable resources for collaborators.

Despite more than two decades of research and regulation attempts, the regulation of mercury in the United States remains in its infancy. The findings of this research on the regulatory landscape of mercury in the northeastern United States are presented in Table 11. Table 11 portrays a summary of findings as presented in Table 3 within the study region in terms of regulatory scope and stringency, collaboration, and issue salience. All states have issue salience regarding mercury contamination of state surface waters; however, each state chooses to address these concerns differently. Connecticut and New Hampshire have the most comprehensive regulatory landscapes, evidenced by the widest scope and broadest stringency within the study area. The District of Columbia and West Virginia have the least comprehensive regulatory landscapes, and issue salience variables indicate these two states have substantial mercury contamination concerns. A lack of US EPA recommendation or guidance for water column SWQS makes it difficult to compare SWQS across states because many have not adopted fish tissue concentration SWQS.

Table 11. Summary of Results

State	Scope of Regulations	Stringency of Regulations	Collaboration	Issue Salience
CT	Coal Power Plants, Dental Discharges, Waste Stream	Waste Incineration regulations more stringent than US EPA; SWQS more stringent than US EPA reccomends	Yes	State Research; statewide mercury fish consumption advisory for freshwater
DC	Same as US EPA	Water Column SWQS	No	statewide mercury fish consumption advisory for all state waters
DE	Coal Power Plants, Waste Stream	Same as US EPA	No	statewide mercury fish consumption advisory for all state waters
IL	Coal Power Plants, Waste Stream	Water Column SWQS Only	Yes	State Research; statewide mercury fish consumption advisory for all state waters
IN	Waste Stream	Water Column SWQS Only	Yes	State Research; statewide mercury fish consumption advisory for most inland waters
MA	Coal Power Plants, Dental Discharges, Waste Stream	Same as US EPA	Yes	State Research; statewide mercury fish consumption advisory for freshwater and ocean waters
MD	Coal Power Plans, Waste Stream	Same as US EPA	No	State Research; statewide mercury fish consumption advisory for all lakes
ME	Coal Power Plants, Dental Discharges, Waste Stream	SWQS more stringent than US EPA	Yes	State Research; statewide mercury fish consumption advisory for freshwater
MI	Coal Power Plants, Dental Discharges, Waste Stream	SWQS less stringent than US EPA	Yes	State Research; statewide mercury fish consumption advisory for all inland freshwater
MN	Dental Discharges, Waste Stream	SWQS more stringent than US EPA	Yes	State Research; statewide mercury fish consumption advisory for freshwater
NH	Coal Power Plants, Dental Discharges, Waste Stream	Waste Incineration regulations more stringent than US EPA; SWQS same as US EPA	Yes	State Research; statewide mercury fish consumption advisory for all state waters
NJ	Coal Power Plants, Dental Discharges, Waste Stream	Water Column SWQS Only	Yes	State Research; statewide mercury fish consumption advisory for all state waters
NY	Coal Power Plants, Dental Discharges, Waste Stream	Water Column SWQS Only	Yes	State Research; statewide mercury fish consumption advisory for all lakes
OH	Waste Stream	Water Column SWQS Only	Yes	State Research; statewide mercury fish consumption advisory for all state waters
PA	Coal Power Plants, Waste Stream	SWQS more stringent than US EPA	No	State Research; statewide mercury fish consumption advisory for all state waters
RI	Dental Discharges, Waste Stream	Water Column SWQS Only	Yes	No state research; no statewide mercury fish consumption advisory
VA	Waste Stream	Water Column SWQS Only	No	State Research; no statewide mercury fish consumption advisory
VT	Dental Discharges, Waste Stream	Water Column SWQS Only	Yes	State Research; statewide mercury fish consumption advisory for all state waters
WI	Coal Power Plants, Dental Discharges, Waste Stream	Water Column SWQS Only	Yes	State Research; statewide mercury fish consumption advisory for all inland lakes
WV	Same as US EPA	Water Column SWQS Only	No	State Research; statewide mercury fish consumption advisory for all state waters

It is clear states such as Connecticut and New Hampshire are making significant progress towards regulating mercury emissions at the source in an effort to solve the problem of mercury contaminated surface waters. Current technology does not offer an option to easily remove mercury from the environment, meaning reactive approaches will not be effective. Those states employing proactive approaches will lead the way in the long process toward mercury remediation of United States surface waters.

Past attempts at mercury regulation and experience with other PBT pollutants, such as lead, indicate mercury is not adequately managed using existing regulatory methods. A comprehensive federal regulatory approach is necessary to fully address both the acute impacts of local deposition and the global hazard mercury presents. A comprehensive federal approach may help in identifying and implementing new mercury management approaches by creating continuity and fostering cooperation and collective learning.

In situations characterized by high uncertainty, high stakes, disputed values, and urgent decisions there is no simple solution. The issue of mercury emissions relies heavily on the analysis of risk, and is ultimately a value judgment regarding how much risk society is willing to accept (Funtowicz and Ravetz 1992). Various uncertainties are inherent in risk analysis, some of which cannot be reduced. Collecting more data and increasing our understanding of the relevant processes is an important goal, but will not necessarily resolve all uncertainties or offer a clear solution. Perhaps more important than additional data, is the quality and type of dialogue among stakeholders (specifically the public and industry). In order to agree on an acceptable level of risk, the discussion must not focus on more data collection and monitoring, but on the values inherent in the hazards of mercury in our environment.

As the US EPA and various state environmental agencies attempt to manage mercury, the greatest challenge is the uncertainty surrounding the environmental fate and behavior of mercury in the environment. Lessons learned through the challenge of mercury management will prove valuable in future efforts to reduce other pollutants such as nitrogen, phosphorus, pesticides, and other heavy metals, in United States' water and land resources.

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